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ABSTRACT

Questionnaires returned by science teachers across the country and reaction forms completed by selected high school, college, and adult learners, were analyzed to judge the impact of, and acceptance by public television audiences, of five half-hour programs broadcast in the "Spectrum" science series, produced with financial support from the National Science Foundation. A general significant knowledge gain was achieved by all three groups of learners; science teachers and learners surveyed reported satisfaction that science programs should be broadcast for the general public and that in addition to gaining a high rate of acceptance by laymen, the programs encouraged and maintained interest in science. (The document includes the questionnaire, study guides, selected questionnaire comments, adult sample responses on the seismology broadcast, and genetics reaction forms. One appendix removed because of poor reproducibility.) (author/ly)

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SCIENCE PROGRAMMING
AND THE
AUDIENCES FOR PUBLIC TELEVISION

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SCIENCE PROGRAMMING AND THE AUDIENCES FOR PUBLIC TELEVISION

An Evaluation
Of Five Programs in the
NET "SPECTRUM" Series

Questionnaires returned by science teachers across the country and reaction forms completed by selected high school, college, and adult learners, were analyzed to judge the impact on and acceptance by public television audiences, of five half-hour programs broadcast in the "Spectrum" science series, produced with financial support from the National Science Foundation. A general significant knowledge gain was achieved by high school, college, and adult learners; learners and science teachers surveyed reported a satisfaction that science programs should be broadcast for the general public and that in addition to gaining a high rate of acceptance by laymen, the programs encouraged and maintained interest in science.

INVESTIGATOR'S NOTE

The NET Educational Services Department is greatly indebted to those whose cooperation made possible the completion of this investigation. Our principal consultant for the field work, the questionnaires and their administration, was Peter C. Benedict, associate professor of geology at the State University of New York at Albany; for the report itself it was Stephen C. Johnson, lecturer in the School of Education and program supervisor, Field Services Department, Audio-Visual Center at Indiana University. Milton R. Stern, director of the University Center for Adult Education at Detroit and Daniel Woodard, vice principal at White Plains High School, White Plains, New York, made possible the administration of tests at their respective institutions. Raymond P. Zelazny, coordinator of course programs, conducted and reported the research at the University Center. The tests at White Plains High School were administered by science teachers C.D. Heath (biology) and S.C. Tamboia (earth science). Miss Nancy Freitag conducted a special test group with graduate students of education at the University of Michigan. Miss Bobbi Jaison assisted in the tabulation of questionnaire responses.

The NET Science staff gave their full cooperation; David Prowitt, science editor, and producers Robert Dierbeck, Bert Shapiro, and Eliot Tozer helped not only as authors of study guide copy but also in advising on questions to be asked in various questionnaires and in analyzing replies.

Henry C. Alter
Director
Educational Services, NET

Summer, 1969

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INTRODUCTION

This report is an evaluation of the impact and acceptance of five programs produced with financial support from the National Science Foundation and broadcast in April and May, 1969, by National Educational Television* as part of the continuing weekly science series, "Spectrum."

The Programs

1. Exploring the Universe--In Radio and Light (April 30)**
   New developments in radio astronomy and optical astronomy to further understanding of the nature of stars, galaxies, quasars, and past and present of the universe itself.

2. Changing the Weather (May 7)
   Recent research in meteorology, focusing on the problems and methodology of altering storms and controling climate.

3. The Trembling Earth (May 14)
   Current issues in seismology to discover the structure of the earth and major geological processes in predicting earthquakes.

4. Stop or Go--An Experiment in Genetics (May 21)
   Experiments in understanding the factors which govern heredity, chemical language, and pursuing the ability to alter genetic formulas.

5. A Visit with Harold Urey (May 28)

The Nobel-Prize-Winner, chemist, physicist, creative thinker, and teacher discusses the major influences on his life and the conclusions he has reached about science and our world.

Originally, these programs were not broadcast in sequence. Two of them were aired late in 1967, two early in 1968, and one in the spring of 1969. In order to make possible the evaluation reported here, the NET program department arranged to have the first four programs repeated at weekly intervals, following the premiere of the latest one.

**The dates (Wednesdays) listed are those of the network "feed" at 8:00 p.m., E.D.T., but, as is customary, individual stations retained the option to air the programs at those times or to tape them for broadcast at a later time. Many stations also scheduled a repeat broadcast within a few days. We can assume with confidence that virtually all the NET affiliates did air the five programs at some time during the week of the network feed.

Method of Investigation

As outlined in the original NET proposal to the National Science Foundation, the evaluation was planned in two major phases: (1) a mail questionnaire (see Appendix A), addressed to teachers of high school and college science, elicited responses based on viewing the programs broadcast on television; (2) selected college, high school and adult learners were shown the films in small groups and were asked to complete a different reaction form at that time.

The mail questionnaire provided reactions to each of the five programs, while the film screenings with learners were limited to two programs (this was necessary because of the relatively time-consuming task of obtaining prints, shipping them to different locations, and using instructional time to obtain feedback). Two films were selected for projection to represent opposite poles in terms of ease or difficulty of the subject matter. The overall mail responses indicate conclusively that, had it been possible to project and test student reaction to the other three programs, responses to them would have fallen somewhere between the responses obtained on the two programs selected.

Phase I: Questionnaire for Broadcast Viewers

In the first three months of 1969, mailing lists were obtained from two sources to mail questionnaires to science teachers at secondary schools and at colleges and universities.

From the National Registry, National Science Teachers Association, NEA:

	10,000	biology teachers, high school faculty
	10,000	earth science teachers, high school faculty
	10,000	heads of science departments, high school faculty
TOTAL:	30,000	high school teachers of science

From the Educational Directory of Marion, Ohio:

	3,230	biologists, college and university faculty
	2,682	geologists and meteorologists, college and university faculty
	802	astronomers, college and university faculty
TOTAL:	6,714	college and university teachers of science
GRAND TOTAL:	36,714	high school, college, and university teachers of science

Each mailing included a questionnaire, one or two study guides which corresponded to the addressee's field of specialization (see Appendix B) and a postage-paid reply envelope, coded to the mailing list used. The mailing was timed to reach most recipients two weeks to ten days prior to the first scheduled broadcast.

Phase II: Evaluation for Learners in Test Groups

(The College Sample of 150 students in 6 groups)

Late in 1968 Peter C. Benedict, Associate Professor of Geology on the Albany campus of the State University of New York (SUNYA) was asked to read the study guides and to screen the films, in order to design instruments of evaluation. Professor Benedict also agreed to conduct some of the evaluations with his students and arrange for others to be conducted by a colleague on the SUNYA faculty.

(The Adult Sample of 160 adults in 8 groups)

Shortly thereafter, arrangements were made with Milton Stern, Director of the University Center for Adult Education in downtown Detroit to conduct similar tests with several groups of adults enrolled in various courses conducted by the Center.

(The High School Sample of 195 students in 16 groups)

Also, agreement was obtained from Daniel Woodard, Vice Principal at White Plains High School, White Plains, New York, to conduct the tests with groups of high school students there.

The group screening and testing phase began in February and ended in May, 1969.

RESULTS

The portion of the report which follows falls logically into two main sections, one on the mail questionnaire, and one on the test groups, followed by some general conclusions.

The findings and conclusions reported here may be supplemented and refined through subsequent research and replication. The raw data contained in nearly 1,000 test papers and questionnaires obviously number in the tens of thousands and may be analyzed in many ways. It is our intention to make them available to an educational researcher at the Indiana University Audio Visual Center who is working in the area of the evaluation of messages in educational materials. We hope that his work will develop important additional dimensions, as it is integrated with the current state of the art in "product evaluation."

I. Results: The Mail Questionnaire

This phase of the evaluation was clearly the more innovative of the two procedures, for several reasons. First, it was geared entirely to television, viewed at home, largely outside of school hours. Second, although addressed to professionals, it was designed to gauge the program's relevance to laymen. Third, without offering an inducement other than an offer of additional study guides, it asked for a greater effort on the part of the respondent than most surveys: the respondents were required to ascertain the actual local air time for the program they were to see, they had to keep that time in mind for a period ranging from ten days to several weeks, make the effort and take the time to view one or more of the half-hour programs, and then communicate their reactions to the investigator.

In order that this task not appear overly formidable, it was decided to ask each respondent to review just one, or at the most two, of the programs closest to their indicated field of specialization. Accordingly, most of the biologists received only the study guide for the genetics film, the geologists received the seismology guide and the meteorology guide or just one of the two, the astronomers were sent both the radio astronomy guide and the one on the Harold Urey interview, and the science department heads received the Harold Urey guide and any one of the other four.

It should be noted in this connection that 42% of the respondents took the trouble to request one or more of the guides that had not been sent to them originally--clearly an indication of the usefulness of concomitant materials to aid study.

Overall Responses to Questionnaires

As indicated above, a total of 36,714 names and addresses were used in mailing the questionnaires. Normal attrition, through spoileage of labels and envelopes, brought this total down to 34,986 pieces actually mailed. Direct mail specialists estimate that roughly 10% of a mailing of this size is undeliverable due to address changes, deaths, loss, and other causes. On that basis it can be assumed that between 31,000 and 31,500 persons actually received the mailing.

Since most of the mailing lists were national in scope (only one of the three NEA lists was limited to six "Major markets,") it must be assumed that a certain number of questionnaires were received in areas not yet served by public television. An estimated 20% of television households in the nation are not served by public television stations, but that figure cannot be used because 65 responses were received from persons who returned the questionnaire with the comment that their area is not yet served by public television, many of them adding urgently worded remarks regretting their exclusion, or exhorting NET to extend its coverage. Despite this, it is fair to assume that an unspecified number of questionnaires, received in non-public television areas, were ignored for that reason. These must be added to other factors, such as the time and effort required for a meaningful response, and the local variations in air date and hour, in gauging the size of the response and its significance. It should be noted that the response to our mail questionnaire may have suffered in some locations because we were not able to inform all recipients of the exact day and hour they could view the program locally.

Altogether, 420 responses to the questionnaire were received. This is between one and two percent, considered an acceptable rate of return from any sample as free from organizational ties to the agency originating the survey as were these teachers, and lacking any tangible benefit. Moreover, some of the respondents, on their own initiative, asked their classes to view the programs and reported a substantial number of reactions, rather than just one response. Some teachers went even further, asking their students to write reports on the program they had viewed, and submitting these. Some of these student papers are in Appendix E.

Some aspects of this investigation--among them the unsolicited student papers--must be viewed as a bonus. Other aspects which might have been anticipated but were not, made precise tabulation more difficult. Among these was the factor that many teachers returned the questionnaire, but did not use the coded reply envelopes, while others used the envelope to return a letter of their own but no questionnaire, and still others wrote letters without using either the questionnaire or the envelope, Finally, some useable responses were received from persons who could not see the program, but wished to comment on the study guides, or on some relevant aspect of public television. An attempt has been made to report all relevant information, despite the fact that these findings will not be easily categorized and that some totals, obviously, will add up to more, and some to less, than 100%.

Table 1: Overall Reaction to all 5 Programs: *

Favorable	143	57%
Mixed**	72	29%
Unfavorable	35	14%

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*See also the "Selected Comments" on each program, Appendix C

**In most cases, respondents actually listed several specifics each under "strong points" and "weaknesses"

Effectiveness of Mail Survey

The most obvious statement that can be made here is that college and university instructors responded in far greater relative numbers than did high school teachers. Numbering only 5,618, or 16% of our total mail count, they returned 127 coded replies out of 342, or 37% of the response. This is further increased by the fact that the great majority of those using their own envelopes instead of ours were college or university instructors.

There may be significance in these figures beyond the scope of this report, apparently supported by other findings about the audiences of public television. Virtually all previous studies of that audience have agreed on one point: the more education one has, the more likely he is to be a regular viewer of public television. It is not unreasonable to suppose. that, among those receiving our mailing, the ones most likely to respond were the more highly educated, and therefore, regular viewers.

The rate of response to all three of the high school teacher lists was below 1% while it was between 2% and 3% for the college and university lists. The smallest of these lists, 788 astronomers, produced the highest return in the sample, but this may have been due to the fact that the radio astronomy film was the first program broadcast in the series, and the only one not broadcast previously. On the other hand, the largest number of response was received for the genetics film (shown fourth) the second largest for radio astronomy (first in the series) followed by seismology and weather. The smallest response was that of the Harold Urey program, but this may be explained by the timing of the broadcast immediately prior to the Memorial Day holiday.

Analysis of the Responses to Individual Questions on the Mail Questionnaire

1. Date of Broadcast: This question was included as a check on the stations' scheduling of these programs. An analysis of the dates given shows that fully one-third of the respondents saw the programs at a time other than the network feed, and about half of these with a one-day delay, when the Eastern Educational Network of more than 25 stations carried them. A number of Western stations apparently aired "Spectrum" on Sunday, four days after the network release, and there was a sprinkling of still other dates as well. Some respondents were vague as to the exact date, and a small number appeared to respond on the basis of the original 1967/68 airing of four of the programs.

2. City in or near which broadcast was seen: The geographic spread of the survey was comprehensive with responses from 44 states and the District of Columbia. (There is no public television coverage in three of the six states not responding.)

3. Is it possible that you might have viewed this program if you had not received this notice? This question, designed to show whether the respondents were aware of public television, was answered as follows:

yes: 60% no: 40%

It is worth noting here that, when an almost identical question was asked of the various test groups, the answers were:

	yes:	no:
High School Sample	37%	63%
College Sample	32%	68%
Adult Sample	77%	23%

While this indicates a tremendous bias in favor of public television on the part of the adult sample, it is not inconceivable that persons who voluntarily take adult education courses, most of them non-credit, would also be the most likely group to view public television regularly, and be favorably disposed toward it. It is also consistent with what is known about the viewing habits of young people that students answered as they did. Both student groups (high school and college) were unlikely to have viewed these programs as they were broadcast. High school students, generally living at home, had a slightly better chance to have seen them than did college students, a segment of the public which is known to see little or no television of any kind.

4. Do you feel that this program presented information about science that the general public should have? Overwhelmingly, this question was answered in the affirmative. The only negative responses came from those who felt that the particular subject matter was too complicated in its substance or presentation to be understood by the general public. Since the following question deals more specifically with comprehension, we had hoped by this question to learn whether teachers in general feel that scientific information should be made widely available, or whether it should remain the province of the expert. Clearly, they favor broad dissemination of scientific knowledge to the general public.

5. Was the information presented so as to benefit a lay person? In some respects, this was the central question for the entire survey, and the real answers to it must be sought throughout the written comments (see Appendix C) and in the letters. Expressed in figures, the answers were:

Table 2: Presentation Suitable to Lay Public:

	Entirely:	In Part:	Not at All:
Universe	15	36	1
Weather	17	22	0
Trembling Earth	17	20	0
Genetics	15	71	6
Urey	7	8	0
	71	157	7

6. Please comment briefly as to strong points and/or weaknesses in the presentation: Representative samples of replies are quoted in Appendix C. They speak for themselves, and dramatize the delicate balance, which the kind of program being evaluated must seek, between a body of knowledge that is vast, specific, and demanding and a method of presentation that must appeal to varied interests and motivations. The following table represents an attempt to summarize the reactions of all respondents to each of the programs inasmuch as the evaluation quotations in Appendix C do not reflect the actual distribution of positive, negative, and mixed responses.

Table 3: Response to Individual Programs:

Title	Favorable	Mixed	Unfavorable	Total
Universe	29	13	10	52
Weather	23	13	4	40
Trembling Earth	28	8	3	39
Genetics	51	35	15	101
Urey	12	3	3	18
	143	72	35	250

In additon to the comments in Appendix C Appendix E includes some letters and student papers of special interest. (Included, as a tribute to the effectiveness of the mailing list, is a spirited letter from the renowned seismologist Charles F. Richter of the California Institute of Technology.)

Analysis of Comments

It is hoped that the comments (in Appendix C) convey the range of reaction received from the sample of professionals. Many seem to focus on whether or not the programs could be understood by the lay viewer. A comfortable majority of individual statements, supported by the weight of the answer given to question 5, ("Was the information presented so as to benefit a lay person?") seem to indicate a positive result. It appears that, except for more diagrams and animated sequences, the producers could not have done a great deal to make these subjects more accessible without compromising the substance that had to be transmitted.

In addition, there is evidence that even the more difficult programs were reasonably well understood by 10th grade students and some 8th graders, viewing on television at home rather than in the classroom. In fact, it does not appear from this survey that those who viewed the films projected in the classroom were significantly better able to understand them than were the viewers of television. The kinds of detail, both on content and on production values, that were observed by television viewers, indicate that the medium is fully capable of conveying the information required by these subjects.

7. In your opinion, could the broadcast have the effect of encouraging young people to seek careers in science? Consistent with earlier expressions of approval, this question was answered as follows:

yes: 188 no: 34

Here it is appropriate to quote the answers given by some tenth graders in an honors section in BSCS(green version) Biology:

"Yes, the overall protrayal seemed honest."
"Yes, unless they hadn't planned on as much work."
"Yes."
"Possibly, if they had a sincere interest in science."
"It could."
"To some degree."
"Yes. Programs such as this tend to spark one's curiosity."

These comments were made about the program "Stop or Go," clearly the one found most difficult by all of the adults, teachers and laymen alike. (See section II, the Test Groups.)

8 & 9. (Optional space for name, address, and request for additional study guides.) As reported, 42% of all respondents did ask for additional study guides. Some, indeed, went beyond the offer we had made and asked for large numbers of guides for one or several classes. Some of these requests were met at the outset, but it was found necessary later to enclose a note explaining that requests had to be limited to a single copy.

As expected, most of the requests for guides came early in the five program series, dropping off toward the end. One kind of response occurred frequently in the beginning--a request for additional guides and questionnaires in order to send in evaluations of subsequent programs. The investigator responded to these requests, using a special code on the return envelopes, but was disappointed to find that they were returned in only one case. Perhaps, in the final weeks of the school year, teachers found it impossible to carry out their earlier good intentions.

II. Results: Learners in Test Groups

The test groups included three samples:

The College Sample of 150 students in 6 groups
The High School Sample of 195 students in 16 groups
The Adult Sample of 160 adults in 8 groups

In general, the procedure was the same for all the test groups. The films were projected and the questionnaires handed out and completed during a regular session of the class or group being tested. Except where the instructor himself administered the test, advance permission was obtained from the regular instructor and the person conducting the test did so as a guest of the instructor. In Detroit, the adult students were given advance notice of the film showings and the test. All of the groups understood clearly that their participation was regarded as a courtesy to NET and that their scores on the tests would have no significance whatever in terms of their standings in the regular course they were taking.

Number and Composition of Test Groups

The College Sample (SUNY, Albany)

Geology 105	21 students	Genetics
Geology 105	22 students	Trembling Earth
Science 112	31 students	Trembling Earth
Science 113	44 students	Genetics
Earth Science 202	16 students	Trembling Earth
Earth Science 202	16 students	Genetics
	150 college students	

Students in Geology 105 are freshmen who may major in science; Science 112 and 113 are service courses taught for non-science majors; Earth Science 202 has an enrollment of juniors and seniors majoring in the sciences.

The High School Sample (White Plains H.S., N.Y.)

10 Biology Lab Sections (Juniors and Seniors)	105 Students	Genetics
6 Earth Science Classes (Juniors and Seniors)	90 "	The Trembling Earth

The Adult Sample (University Center for Adult Education, Detroit)

Fundamentals of Film Production (Credit Students)	15 Students	The Trembling Earth
Fundamentals of Film Production (Credit Students)	11 "	Genetics
Contemporary Thought and Writing (Housewives)	26 "	The Trembling Earth
Contemporary Thought and Writing (Housewives)	27 "	Genetics
Basic Writing Class (ATTAC, Poverty Program)	15 "	The Trembling Earth
Beyond 60: Sounds of Silence (Senior Citizens)	20 "	The Trembling Earth
Writing and Language (Saturday Class)	32 "	The Trembling Earth
Graduate Students in Education (Univ. of Mich.)	14 "	The Trembling Earth
total	160 Adults	

Grand Total 505 Subjects in all samples

Analysis of Reaction Forms--College Sample and High School Sample

All of the test groups operated under the necessary handicap of the paper-and-pencil instrument and the "testing situation" associated with it. The results obtained should not, however, be interpreted in the same way as test papers used in class instruction. The "passing grade" obtained in the usual students' tests signifies responses to a complex, purposeful process which a single television program (film) cannot be expected to replicate. Instead, when one considers the conditions under which most viewing of television takes place, it seems more appropriate to assume that, because of the technical nature of the information, knowledge was at a zero level before viewing the film. In that case, anything above chance response indicates knowledge gain which is logically significant, even where it is not statistically significant. This factor is underlined when one considers the probable numbers of persons viewing these films on television--likely in excess of one million for each film.

With populations of that size, even the most random learning represents significant information transfer, and the evidence indicates that the learning which took place was far more than random.

To measure the learning effectiveness of the films, a simple scoring system was used, in which one point was awarded for giving a really relevant answer, one half point for showing some understanding or giving a partially correct answer, and zero for giving a wholly incorrect answer or no answer. *

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*For the "Trembling Earth" reaction form, see Appendix D; for the "Stop or Go" reaction form, see Appendix F.

With one exception, the test groups achieved better scores on "The Trembling Earth" than on "Stop or Go," probably because the former was both easier to understand and provided more opportunities for emotional identification. Throughout all the groups, surprises were at a minimum, with higher scores being achieved by more advanced students (and, among the adult sample, by persons with more schooling).

It is a matter for speculation whether scores could have been significantly improved by the inclusion of more diagrams (desired by many respondents to the mail questionnaire,) or by having the film provide a summary or "wrap-up" feature which students have come to expect in the more didactic films produced for classroom use. Whether or not this is the case, the requirements of television presentation had to govern the format used, calling for a non-didactic approach.

In the context of television presentation, special attention needs to be paid to the "opinion" questions on the reaction form, and their possible relation to knowledge gain as seen by the viewer in the light of his original interest and the loss, maintenance, or increase thereof before and after viewing.

Thus it is possible to compare the answers to Question 1, which asked if the respondents would have viewed the film on their own at home, and Question 3, which asked if the film had held the viewer's interest.

The following table traces this dimension for a sample of the high school students for each of the two films.

Table 4: Original Interest and After-viewing Interest
(White Plains High School)

Question 1	Question 3	Percentage of Sample	
		Seismology	Genetics
No	Yes	48%	38%
Yes	Yes	32%	22%
Yes	No	10%	2%
No	No	10%	38%

It is clear that the seismology film fared better with this sample than did the genetics film. Distortion and bias are evident in the number of students who said (after viewing,) that they would, or would not, have watched the film on their own. For the more "successful" film, 58% said they would not; for the less successful, 76% said the same. They were projecting their lack of approval into their estimate, although it might be argued as well that more young people would be inclined to view a television program on earthquakes than one on genes.

However, the more encouraging evidence seems to be that whatever the estimate of original interest, majorities of both groups said that the films did hold their interest when they saw them: 80% said so for seismology, 60% for genetics. The combination expressing the most disappointment--those with original interest who lost it when viewing the film--is so low in both cases that it is probably without statistical significance.

In a cross section of the college sample, where higher motivation may be inferred, the two dimensions of Yes/No and No/No did not show up at all for the seismology film, and Question 3 got an almost unanimous Yes answer. By contrast, the genetics film ran into the same bias described for the high school sample--two thirds answering No to Question 1, and the after-viewing approval was down from 100% to 75%.

Achievement with respect to the content questions appears consistent with the foregoing observations. Reaction forms were graded and a Mean Score used throughout the samples. Correct and relevant answers to each question would result in a score of 100.

Table 5: Mean Scores Achieved in Test Groups
(High School and College Sample)

	Seismology	Genetics
High School Sample (N:47)	44%	
High School Sample (N:39)		36%
College Sample (Freshmen, General Science; N:31)	42%	
College Sample (Freshmen, Geology; N:22)	54%	
College Sample (Juniors and Seniors, Geology; N:16)		77%

Instructors have reported that, except for the college juniors and seniors, none of the students had had instruction paralleling the content of either film. They were, in fact, thought to be representative of the average viewer of public television in educational attainment, if not in age. The college seniors scoring 77% on the genetics film, even though their major was geology, represent a group of advanced science students who were easily able to handle a subject outside their major field, an indication of the perimeters of utility of this particular film.

The significance of these scores, as expressed by one consultant, is that "...if the viewers of these films are able, on the average, to show an understanding of about half of the many points discussed, then the film must have been effective. Also, if the film maintains the interest of people who would not have tuned their sets to it on their own, this shows what impact it could have on the general public, if they could be persuaded to view it." The same consultant points out that "... in the time of one half hour a significant increase in knowledge about a highly complex subject was effected."

Analysis of Reaction Forms--Adult Sample

Because of its greater relevance to this survey, the adult sample will be discussed in more detail than the other two samples.

When the report on the Detroit adult test groups was submitted*, the covering letter had this to say about "Stop or Go":

> "I did take the genetics film and show it to two groups after which point I decided to discontinue showing it. The response of the first two groups was very hostile and negative, and I felt I would be taking unfair advantage of the respondents if I continued showing the film. I do have 38 completed questionnaires which you may have."

This confirmed once again that few people are indifferent about this film--they either like it a lot, or they hate it. The investigator felt that the Center was right not to persist in further screenings, and decided to summarize the extant questionnaires. These findings will be reported following the data on the completed tests with "The Trembling Earth." Meanwhile, it should be kept in mind that "Stop or Go" yielded twice as many mail questionnaires as any other program, and that college juniors and seniors scored very high in the test following their screening.

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* With minor alterations, this is the report prepared by Mr. Raymond Zelazny of the University Center for Adult Education. The changes made are designed to incorporate data on three groups omitted in the report: two at the University Center who viewed "Stop or Go," and one group of graduate students at the University of Michigan who viewed "The Trembling Earth."

NET requested the University Center for Adult Education to survey at least 100 adult education students. The questionnaire prepared by NET was used by all the students in the survey. A cross section of adult education courses was selected to roughly represent students who typically participate in various UCAE activities. The sample was selected by type of participant--university credit students, poverty program trainees, senior citizens, housewives, workshop and general instruction students. These people are presumed to represent a cross section of the adult community based upon UCAE experience. Their enrollment in a formal program of instruction is assumed to suggest a favorable disposition toward education.

The instructor of each group was asked for permission to conduct the project with his students. Those instructors who agreed were asked to announce the project to their class the session before it was to be conducted. The survey was conducted during the regularly scheduled class period. Attendance was reported as normal for all groups. The group was given the following information: (1) the purpose, sponsors and general conduct of the study; (2) two kinds of questions appearing on the questionnaire were explained as follows: a) questions 1 through 6 were to reflect expressions of viewers opinion; and b) questions 7 through 19 were questions about the film's content. The half-hour film was then shown. Questionnaires were distributed, completed and returned. This procedure averaged about 15 minutes.

In the tabulation (see appendix D) opinion questions were separated from content questions. Various comments about the film's interest are charted separately and appear in Table I of appendix D. The content questions were scored on the basis of one point for a correct answer; $\frac{1}{2}$ point for a partially but correctly answered question, or an answer which was partially incorrect; and no points for a blank or an incorrect answer. Table I of appendix D contains responses to the opinion questions and answers to the content questions. Correct answers to content questions were determined from the film and from a study guide provided by National Educational Television. A tabulation of the scores is contained in the summary of each group--Tables II-VI of appendix D respectively. Tables II-VI reflect each group's response and performance.

Analysis of Responses to Individual Questions on the Reaction Form
(Adult Sample)

"The Trembling Earth"

Opinion Questions 1 - 6

Question 1. Would you have watched "The Trembling Earth" on TV at home, if you had known about such a broadcast?

90 - yes 17 - no

Eighty-four percent (84%) of the respondents indicated that they would watch the program. *)

See Master Tabulation, appendix D

Question 2. Do you feel that enough explanations of terms and processes were offered in the film?

78 - yes 30 - no

Seventy-two percent (72%) of the respondents felt that the film provided enough explanation of terms and processes.

See Master Tabulation, appendix D

Question 3. Did the film hold your interest? (Please explain briefly why it did, or did not.)

99 - yes 15 - no

Adult education students indicated a general interest in the earthquake film. The students indicated that their interest in the film was held primarily by the use of vivid illustration, a current events topic, and a well organized presentation.

See Table VII, appendix D

Question 4. In your opinion, which of the groups listed below would benefit most from seeing this film? (Geologists, Scientists other than geologists, The general public, Persons who might choose geology as a career, People who live in an earthquake-prone area.

169 - Non-science 49 - Science

See Master Tabulation, appendix D

* When the two groups viewing "Stop or Go" are included, the response drops to: yes: 77% No: 23%

Question 5. Do you feel you gained some knowledge about: a) the behavior of the earth's crust; b) the interior of the earth; c) the way scientific information is gathered; d) the way it is evaulated, e) the nature of waves.

The film offered a general knowledge gain. The gain was most prominently reflected in "the behavior of the earth's crust" and "the way scientific information is gathered."

See Master Tabulation, appendix D

Question 6. Did you know what a seismograph is before you saw this film?

74 - yes 34 - no

Sixty-eight and four tenths percent (68.4%) of the respondents indicated that they knew what a seismograph was before the film was shown.

See Master Tabulation, appendix D

Content Questions 7 - 19

Question 7. If you did not know, do you know now what it is?

20 - yes 14 - no

Of the 34 respondents who answered no to Question 6 20 answered yes to Question 7. This should reflect an information point gain in Question 8 and 9.
(Possible 40 points.)

The highest possible score for Questions 8 - 19 was 12. The respondents produced mean scores as follows: (To the nearest tenth) College students 7.3; general course and workshop students 5.1; housewives 3.5; lower socio-economic group 2.5; senior citizens 2.4. The overall group mean was 4.16.

Most adult education students (84%) would have watched the program at home on television if they had known about such a broadcast. The vivid illustrations, well organized presentation and current news and values which held the viewers' interest. Terms and processes were adequately explained for most of the respondents (72%), but these explanations were not translated into answers to content questions as reflected by the total mean score (4.16 out of a possible 12). The respondents indicated that the film would benefit the non-scientist more than the scientist (more than 3:1). The film provided most information about the behavior of the earth's crust (4:1) and the way scientific information is gathered (7:1). Although many respondents (60%) indicated that they had a specific information gain (Question 7) they were unable to translate that gain into written answers to specific questions about the information (Questions 8-9).

One of the problems with an evaluation such as this is that non-credit students are generally not accustomed to taking tests whereas the credit student is. This suggests a pre-disposition toward the pencil-paper instrument provided by NET which would favor the group accustomed to tests.

The scores from the content portion of this survey bear out the contention by showing a substantially higher average score (7 1/3) by the credit group. Also, the specific information gain question (7) indicates that the one individual who did not know what a seismograph was before the film knew what it was after. This was demonstrated by the information gain point increase of two out of a possible two.

The opinion expressed in Question 2 was that an adequate explanation of the terms and processes was offered. This is contradicted by the respondents' inability to record answers about the film's content as evidenced by the mean score of 4.16 out of a possible 12. Based upon the instructor's experience and assessment of the film, it was predicted that the final rank order of the groups would be credit students, housewives, general audience, senior citizens and poverty program people. The post-survey outcome ranking conformed closely: credit students, general audience, housewives, poverty program people, senior citizens.* A radical change in this ranking or a closer grouping of scores might indicate a greater effect on learning due to the film.

Table 6: Mean Scores Achieved in Test Groups
(Adult Sample)

	Seismology	Genetics
Credit Students (Film Production; N:15)	60%	
Graduate Students (Education, UofM; N:14)*	59%	
Writing and Language (N:32)	42%	
Credit Students (Film Production; N:11)		36%
Housewives (N:26)	29%	
Poverty Program (N:15)	21%	
Senior Citizens (N:20)	20%	

As reported by Mr. Zelazny, these groups somehow could not come to grips with the genetics film. The group for which a score was obtained (Credit Students,) actually did far better even with this film than some of the educationally disadvantaged groups did with the easier film, although its own score dropped by 24%. Yet, when compared to reaction forms the same individuals had completed for the seismology film, these forms expressed frustration, even irritation. This was even more marked for the only other group that was shown the genetics film, the housewives. In both groups, the handwriting appeared more careless, and comments such as "too scientific and technical," "too deep," abounded.

---

* The graduate students' group was not part of Mr. Zelazny's assignment.

The two groups viewing both films also showed marked variations in the opinion questions. Their combined answers to Question 1, (prior interest,) were: Seismology--Yes: 32, No: 8. Genetics--Yes: 20, No: 18. For Question 3, (interest maintained,) the answers were: Seismology--Yes: 38, No: 3. Genetics: Yes: 16, No: 20. This represents the single instance in the survey where a majority reported that a film had not held their interest.

In general, the scores obtained in the adult sample are far from disappointing. Some were actually higher than those of the student samples, while those that were lower came from groups of persons whose education was deficient. In addition, the adults as a group are, of course, far less accustomed to the testing situation than are the students.

CONCLUSIONS AND DISCUSSION

It is evident that the five science programs broadcast by NET reached a high level of acceptability and information transfer.

Both learners and professionals indicated that their attitudes toward the content and treatment of the various science topics were essentially positive, and were enhanced or maintained throughout the presentation.

One problem with this kind of evaluation is the relative lack of precision concerning "instructional" goals. When educational films are evaluated for curricular integration, instructional utility is measured against precise specifications, keyed to specific objectives and courses of instruction. In public television programming the problem is quite different. Not only is there no particular teaching objective or audience established, but the motivation of viewers may vary from a highly specific, active, professional interest in the subject to an "entertain me, if you can" passivity.

In some respects the five programs, along with most others in the "Spectrum" series, tried to do two things considered by some educators to be opposite: we want to teach and we want to "entertain," both in an environment we do not control, and in which it is up to the individual viewer whether he chooses to be taught, to be entertained, or neither. This presents the television producer with a challenge and an opportunity. The challenge is to live up to reasonable professional standards; the opportunity is to appeal to large numbers of persons with the hope of awakening an interest in science.

Even so, the question remains whether the film should, for example, increase by 10 percent the knowledge of a viewer already familiar with the subject matter, or by 50 percent the knowledge of one never before exposed to it. This research seems to indicate that we were able to appeal to both kinds of viewers, well informed and uninitiated, but that these results varied strongly from one film to another.

Our approach to this evaluation has been eclectic; there are few precedents to guide us. Even in the seemingly more precise context of purely instructional films and television programs there are few absolutes, as evidenced in this research rationale for the Educational Products Information Exchange by Robert E. Stake*:

> No product evaluation can be complete without a survey of the preferences and priorities of the many groups who use the product, or who may benefit or be injured by it.
>
> ...
>
> Every product can, of course, be described in a variety of ways, and comparisons among products can be made on many different grounds. Two dictionaries, for example, may differ as to number of words defined, size or type, durability of binding, and attractiveness of illustrations. They may differ, too, in less tangible matters, such as the thoroughness of definitions or the sanctity in which formal grammar is held. One dictionary is likely to be better for some purposes, another for other purposes. It will be the responsibility of the researcher to describe the dictionaries as fully as he can, then to indicate the conditions under which he knows or suspects that individual dictionaries will do a good job (and, sometimes, which dictionary will do a better job.)

We felt justified in going our own way to try to discover something about the "instructional utility" of these programs, and also to seek information about viewing habits and attitudes toward science on public television.

The role of public television in disseminating scientific information to the many audiences it serves is affirmed in the results analyzed in this investigation. Films such as these in the "Spectrum" series are documented reports of current research in basic and applied science. They utilize the techniques and expertise of, on the one hand, the scientists themselves, and on the other, the professionals of public television. The

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*Excerpts from A Research Rationale for EPIE, by Robert E. Stake, Educational Products Information Exchange; The EPIE Forum, Vol.1, No.1, Sept., 1968, pp. 7 & 8.

"mix" produced by this collaboration amounts to an unexcelled, highly communicative learning opportunity for millions of persons of greatly varying backgrounds and levels of sophistication. The word "opportunity" is central, for public television does not "teach" in the conventional sense. Rather, it provides opportunities for learning, blueprints for further involvement. Many viewers seek these consciously, but many more receive them subliminally. In some the effect may be sharp awareness, even genuine knowledge. In others it is more tentative, a sampling to which they may return later.

As viewing of public television increases, it is inevitable that the intellectual and aesthetic tone of the nation's communities is raised and the public helped in making wiser choices in crucial issues. Clearly, science embodies many such issues, and filmed reports such as these are fundamental to the existence of an informed and enlightened public. They thus perform a service of high priority, and one which may not be similarly available in any other medium of communication.

Appendix A

Mail Questionnaire

APPENDIX A

NET

NATIONAL EDUCATIONAL TELEVISION
10 COLUMBUS CIRCLE NEW YORK, NEW YORK 10019 (212) 262-1200

MEMO to: Science Faculty and Administrators

From: Educational Services, NET April 1969

Subject: Evaluation of five science programs

Searching for a mysterious source of energy in space; trying to turn a harmless cloud into a rain storm; discovering how to predict when disastrous earthquakes will occur; reading the "language" of genetics, and visiting a world-renowned scientist--these are experiences in store for viewers of five half-hour programs to be broadcast this spring over most of the NET network.

Produced with financial assistance from the National Science Foundation, the programs are, in the order of broadcast:

Exploring the Universe--in Radio and Light
Changing the Weather (Color)
The Trembling Earth (Color)
Stop or Go--an Experiment in Genetics (Color)
A Visit with Harold Urey

printed red

The network broadcast schedule for the five programs will be weekly, beginning at 8:00 p.m. Eastern Time on April 30, and ending on May 28. However, local ETV listings should be consulted in every case, as stations may delay (or repeat) programs in many areas of the country.

NET asks for your help in evaluating the effectiveness of these programs. We are especially interested in learning whether they can help bridge gaps in the lay public's understanding of science. Please help us by returning this form after viewing at least one of the five broadcasts. A return envelope, requiring no postage, is enclosed for your convenience.

red

You will also find enclosed one or more study guides of programs in your indicated field of specialization. Please use them as a means of acquainting yourself and your students with the program. In your evaluation, however, please bear in mind that the average home viewer will not usually have such a guide available.

NET attempts, in its continuing science programming, to present information in such a way that the lay public's appreciation of science is increased. Although we feel that these television programs can also enrich the science curriculum, the principal aim is to provide information to the viewer at home.

You can help significantly in this effort by taking a few minutes to give us your opinion of the approach we have taken, and any suggestions as to how it might be improved.

red

If you are able to view more than one of the five programs, and would be willing to give us your reaction to them, please feel free to use additional sheets. The use of your name and/or address is optional.

May we thank you in advance for your cooperation.

(please turn page)

To: Henry C. Alter, Director of Educational Services, NET

Subject: Evaluation of ______________________________
Title of Program

1. Date of broadcast: ________________

2. City in or near which broadcast was seen: ______________

3. Is it possible that you might have viewed this program if you had not received this notice?
yes____ no____

4. Do you feel that this program presented information about science that the general public should have?

____

5. Was the information presented so as to benefit a lay person?

Entirely_____ In Part_____ Not at All_____

____

6. Please comment briefly as to strong points and/or weaknesses in the presentation:

7. In your opinion, could the broadcast have the effect of encouraging young people to seek careers in science?

____

8. (OPTIONAL) Your name: ______________________________

Address: ______________________________________

9. If you would like single copies of study guides not enclosed, please list here the titles you want (and complete your address.)

____

____

Appendix B

Study Guides

SPECTRUM

NET

SPECTRUM is the continuing weekly science series from National Educational Television. EXPLORING THE UNIVERSE — IN RADIO AND LIGHT is #93 in the series.

This viewers guide was produced with financial support from the National Science Foundation.

For additional copies write:
Educational Services, NET
10 Columbus Circle
New York, N. Y. 10019

EXPLORING THE UNIVERSE -

IN RADIO AND LIGHT

Optical astronomy is one of the oldest of all sciences, while radio astronomy is one of the youngest. Will the new science of radio astronomy replace the older astronomy of light? What is the relationship between the two astronomies? In the film called, "Exploring the Universe—In Radio and Light," we attempt to answer at least some of those questions.

Early astronomers studied the motions of the sun and the planets and catalogued the comparatively few stars in the sky that were visible to the naked eye. As optical telescopes were first used, and as they increased in size, optical astronomy moved out into a universe of seemingly unlimited space and an unimaginable number of stars.

Optical astronomers have shown how stars might have been born, how they probably evolve through different stages of nuclear transformations, building heavier and heavier elements, and then how they finally die or, as Dr. Allan Sandage puts it, "become clinkers on the stellar ash heap."

The motions of stars and the huge clouds of gas in many parts of the Milky Way Galaxy were studied by optical astronomers. They measured the distances of other galaxies and found that the nearest galaxies are millions of light years from earth and the most distant observable galaxies billions of light years away. Astronomers found also that galaxies were moving away from earth at speeds proportional to their distances. Optical astronomy, which began in ancient times, has revealed an enormous, expanding universe of billions of stars and galaxies.

Radio astronomy began in 1932 when Karl Jansky discovered, almost by accident, that radio waves were reaching the earth from outer space. At first it was impossible to relate these radio waves to any known object in the sky. Later, as large radio telescopes were built, and better positions were obtained for the radio sources it was possible to identify at least some of the radio sources with optical images. Centers of radio brightnesses on the face of the sun were associated with sun spots and flares. Sources of radio energy in the Milky Way Galaxy were associated with particular gas clouds and exploding stars. Outside our galaxy, certain strange looking galaxies and galaxies that appeared to be in collision were found to be large sources of radio energy.

As a number of observations of a particular radio source are made at a particular radio frequency, contour lines can be drawn that show the radio brightness of the source in much the same way that photographs reveal optical brightnesses. Comparing optical photographs with radio contour lines of the sun, and of many objects in the Milky Way Galaxy there is some agreement in the main optical and radio brightness centers, but many differences in detail. The relationship between the two astronomies is a seemingly confusing one. To try to understand something more of this relationship we can describe the search for strange new objects in the sky called a quasar, which is a short way of saying Quasi Stellar Radio Source. The search for quasars began when radio astronomers found sources of radio energy that could not be identified with any optical images. This is the way our story begins, with the discovery of an unknown radio source.

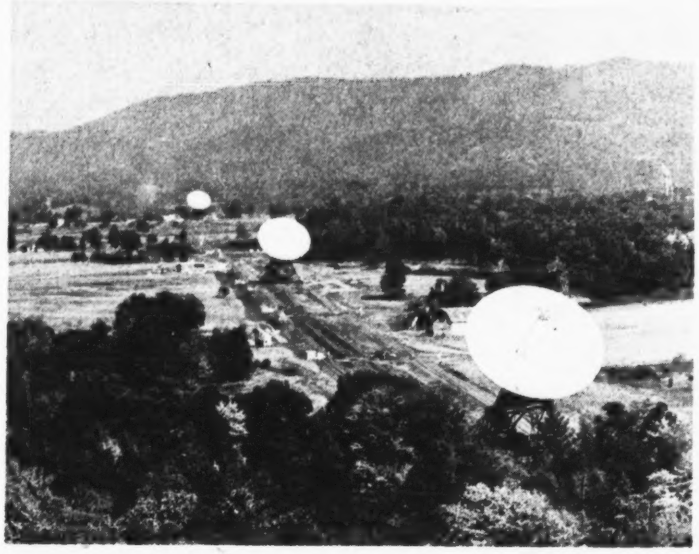
Dr. Campbell Wade, an astronomer on the staff of the National Radio Astronomy Observatory, was conducting a radio survey of a number of strange looking galaxies, to measure and compare their radio brightnesses. When Dr. Wade saw the results of one of these measurements, he found that, while there were radio emissions from around the region of a particular galaxy with strange looking arms, the source of the energy was not the galaxy itself. Further studies showed that the radio energy was coming from some unknown source thousands or perhaps millions of light years away from the galaxy.

The search for the unknown radio source by Dr. Wade, a radio astronomer, and by Dr. Roger Lynds, an optical astronomer, began.

Dr. Wade decided to try to get a more accurate position for the radio source; to do this he had to make use of an instrument called an interferometer.

The interferometer operated by the National Radio Astronomy Observatory is made up of three radio telescopes with 85′ antennas. This huge instrument, together with most of the radio telescopes operated by N.R.A.O., is located at Green Bank, West Virginia in an isolated valley hidden deep in the Allegheny Mountains. Radio telescopes must be isolated from large population centers and from sources of possible radio interference, like automobile ignition, industrial machinery, radio and television broadcasting stations, and electrical power lines. Radio telescopes are not affected by ordinary rain or snow storms. They can operate in almost any weather, and twenty-four hours a day, since sunlight does not affect the radio observations.

A star gives off energy that moves out in all directions, and we can think of this energy as a series of waves. Looking at one of these waves, we would find that it rises in intensity from zero until it reaches a peak, then falls back to zero and reaches an equal but opposite intensity, in a trough or valley of the wave. The wave then returns to zero and repeats the cycle over and over again billions of times as it moves outward. Waves are not all alike. They are different in intensity and in frequency or wavelength, which is the distance between the peaks of the wave. Light wavelengths for example are very short, measured in millionths of an inch. Radio wavelengths on the other hand are very long, ranging up to two miles between the peaks of the waves. It is this difference in the lengths of light and radio waves that makes radio instruments different from optical instruments.

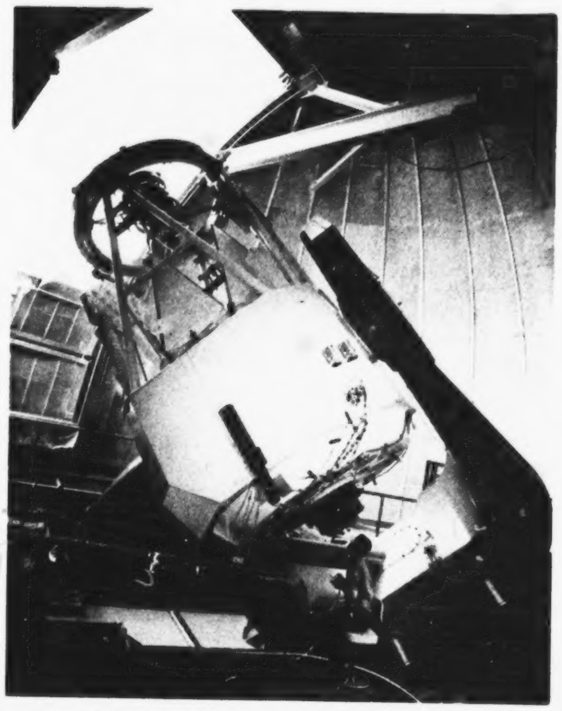


The three radio telescopes with 85 foot antennas that make up a radio interferometer. This instrument operated by the National Radio Astronomy Observatory, is one of the most accurate radio position measuring devices in the world.

The interferometer when set up for position finding, combines its three telescopes into two pairs with one pair simply checking the other pair.

If two telescopes each receive the peak of the same wave at the same instant of time, then the strength of the combined output is double that of the output from one telescope. But the two telescopes are separated by a distance of about a mile, and as the earth rotates, one telescope might then be an inch or two farther away from the source than the other. One radio telescope might then receive the peak of a wave, while the other would receive the trough of the same wave. The two signals would now cancel each other instead of adding and the output of the telescopes would be zero. As the earth continues to rotate, the peak of one wave might reach one antenna as the peak of the next wave reaches the other antenna. Again the combined output would be added. This constructive and destructive interference in radio waves would be repeated over and over again millions of times as the earth rotates. Knowing the precise time the readings were made down to thousands of a second, knowing the recorded output of the two antennas as the earth sweeps past the source, and knowing the distance between the two antennas down to a fraction of an inch, the radio source can be accurately located in space by mathematical computation.

The telescopes have two movements: north-south and east-west. The coordinate system for locating objects in the sky is similar to the latitude and longitude system that we use for locating objects on the surface of the earth. The telescope computer selects the correct motor



The largest optical telescope at Kitt Peak National Observatory with an 84 inch reflector. The concave front surface of the mirror was polished and "figured" to an accuracy of four millionths of an inch.

speed for the correct time to point the telescopes and to keep them on the radio source as the earth rotates. Every five minutes the computer automatically checks the position of each antenna and makes the necessary corrections. The signals are recorded on magnetic tape, which is taken back to be analyzed by the main computer at Charlottesville. This is the only way the information can be analyzed for any practical use of the interferometer. It has been estimated that just one problem solved by the computer in a matter of minutes would take the lifetime of an astronomer, if he were young enough.

Dr. Wade finally looked at the computer results and found a new location in space for the unknown radio source that was many times more accurate than the original position. Within the new circle of error on the sky survey print, he saw two objects. Neither looked very bright nor unusual, but instead they looked like two rather small ordinary stars in the Milky Way Galaxy. This was as far as he could practically go in the search for the radio source. It was now a job for an optical astronomer. He sent the locations of the two starlike images off to Dr. Roger Lynds at the research offices of the Kitt Peak National Observatory, in Tucson, Arizona.

Dr. Lynds agreed to add the two objects to his observing program. The observatory's optical telescopes are located at Kitt Peak Mountain, which is about fifty miles from Tucson. Optical telescopes are kept away from cities because the lights of a city can interfere with the faint images of distant stars and they are placed on the tops of mountains to get as high above the bottom layer of the earth's atmosphere as possible. There are a number of optical telescopes at the observatory used by astronomers for different research projects. Dr. Lynds has the use of the 84" telescope for this particular series of telescope observations, the search for distant quasars.

Either the direct image of an object in the sky can be photographed or, the colors or wavelengths of its light, called a spectrum. Dr. Lynds was interested in photographing the spectra of the two unknown objects, since the spectra would reveal the physical nature and velocity of the objects studied. If one of them was a quasar, its velocity would reveal its huge distance from our Milky Way Galaxy. Because the light of distant objects is so faint, an image tube amplifier was added to the telescope between the beam splitter and the camera. This image tube directs the incoming beam of light to a photoemissive surface that changes the photons of light into a flow of electrons. The flow of electrons is then amplified many hundreds or thousands of times. The amplified or speeded up electrons then strike a fluorescent surface, where the electrons are converted back to photons of light and displayed in much the same way that an image is shown on a television tube. The amplified image can then be recorded on a photographic plate.

Optical telescopes, like radio telescopes, have two movements: east-west and north-south. To photograph a faint object, even with the image tube, exposure of the photographic plate may take as long as several hours. During this time, as the earth turns to the east, a telescope drive motor automatically moves the telescope to the west.

When a photographic plate has been exposed and then developed, the results are a series of spectral lines in the center of the plate. On the top and bottom of the plate are a set of standard spectral lines of a comparison source that have been exposed simultaneously with the light from the star. When the spectral lines of the distant object, which is in motion, are compared to the spectral lines of the comparison source, which is at rest, the motion of the object toward or away from an observer can be determined by the displacement of spectral lines. After examining the spectra of the two objects in the area indicated by Dr. Wade, Dr. Lynds found that the velocity of one of the objects was so small that it was in fact a nearby star in our Milky Way Galaxy. The speed of the other object away from earth however was so great, that the object had to be at a great distance outside the Milky Way Galaxy, perhaps billions of light years from earth. In addition, other characteristics of the spectral lines indicated that the object had to be a quasar.

The results of the efforts of the two astronomers was to find a distant quasar billions of light years away. Over a hundred quasars have been discovered by radio and optical astronomers. Since they are among the most distant objects that can be observed, they may be clues to the size, shape and age of the universe. Further studies of the speeds, distances and other optical and radio features of these objects are going forward. Not only is their disstance and speed of recession of great interest but also the source of the enormous amount of energy they produce. The mechanism for producing this energy cannot be explained by any atomic process with which physicists are now familiar. Perhaps a new source of energy of unbelievable proportions remains to be discovered.

THIS PROGRAM WAS MADE POSSIBLE
BY A GRANT FROM THE
NATIONAL SCIENCE FOUNDATION

EXPLORING THE UNIVERSE — IN RADIO AND LIGHT

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DR. MORTON S. ROBERTS

Cast
DR. CAMPBELL WADE
DR. ROGER LYNDS

Radio Contour Lines of Sun
STANFORD RADIO ASTRONOMY INSTITUTE

Photographs of Sun
McMATH-HULBERT OBSERVATORY OF THE
UNIVERSITY OF MICHIGAN

Radio Contour Lines of Nebulae and Galaxies
BROTHER PETER HENDERSON, F.S.C., Ph.D.
DR. T. K. MENON
DR. D. E HOGG

Photographs of Stars, Nebulae and Galaxies
MT WILSON AND PALOMAR OBSERVATORIES

Executive Produ
DAVID PROWITT

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PURCHASE
Prints of the film described in this guide may be purchased. Agencies interested in purchasing films may obtain preview prints from the Indiana University Audio-Visual Center at no cost other than return postage.

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Rental prints may be ordered by customers within the United States and its territories from their usual rental source or from Indiana University.

INDIANA UNVERSITY AUDIO-VISUAL CENTER
Bloomington, Indiana 47401

There are differences in the instruments and techniques used for radio and optical astronomy, differences dictated by the length of light and radio waves. The information revealed by one compliments and sometimes supplements the information revealed by the other. The objectives, however, of optical and radio astronomers are the same: to understand the nature of stars, galaxies, quasars, and to describe the past and perhaps the future of all celestial objects including the universe itself. To do this it may be necessary to observe the heavens in light waves, in radio waves or in any other way possible.

Dr. Edwin Hubble described the state of affairs in astronomy in the 1930's which is not different from today: "Thus the exploration of space ends on a note of uncertainty. And necessarily so. We are, by definition, in the very center of the observable region. We know our immediate neighborhood rather intimately. With increasing distance, our knowledge fades, and fades rapidly. Eventually, we reach the dim boundary—the utmost limits of our telescopes. There, we measure shadows, and we search among ghostly errors of measurement for landmarks that are scarcely more substantial. The search will continue. Not until the empirical resources are exhausted, need we pass on to the dreamy realm of speculation."

SUGGESTED READING:

Hubble, Edwin. **The Realm of the Nebulae.** Denver Publications Inc.

Hoyle, Fred. **Galaxies, Nuclei & Quasars.** Harper & Row.

Smith, Alex G. and Carr, Thomas D. **Radio Exploration of the Planetary System.** D. Van Nostrand Co. Inc.

Bergamini, David. **Young Readers Edition "The Universe."** Time Life Books.

Wyatt, Stanley P. **Principles of Astronomy.** Allyn and Bacon Inc.

SPECTRUM

SPECTRUM is the continuing weekly science series from National Educational Television. CHANGING THE WEATHER is #88 in the series.

This viewers guide was produced with financial support from the National Science Foundation.

For additional copies write
Educational Services, NET
10 Columbus Circle
New York, N. Y. 10019

CHANGING THE WEATHER

It **should** be easy to make rain.

After all, rainstorms are simple things. You've watched them develop many times. First, wispy clouds glaze the upper sky. The sun sets in a yellow haze. Next morning, the wind suddenly freshens and the clouds thicken and settle closer to earth. Later, the clouds, ragged and dirty, seem almost to touch the chimneytops. And then the rain begins.

A seemingly simple and generally predictable pattern. What's more, in the laboratory, we've learned much about the micro-physics of the precipitation process: how vapor (water in the gaseous state) condenses, forming liquid droplets, and how the droplets grow into raindrops.

But **are** rainstorms simple phenomena? Can scientists modify them? Will we ever bring about a significant change in the weather?

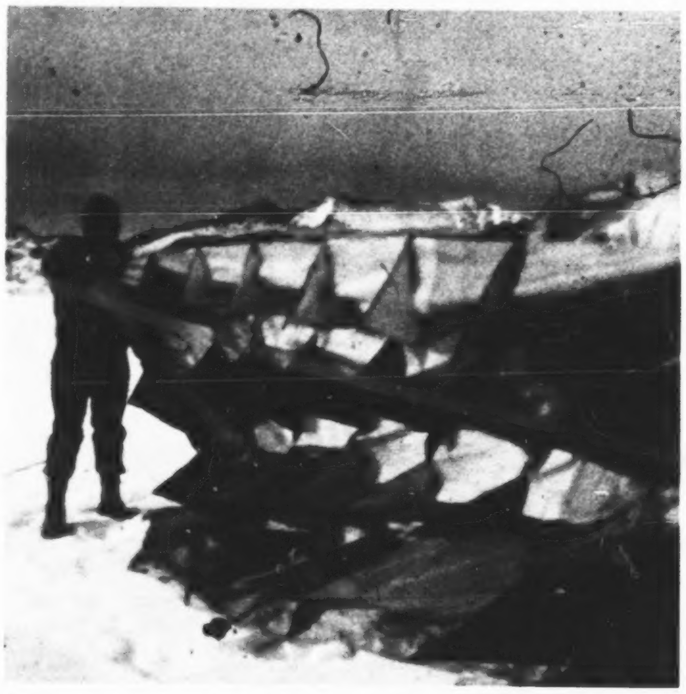
The birth and growth of a raindrop is a complex phenomenon, and the birth and growth of the cloud that nurtures it is even more complex. To make matters worse, it is difficult for scientists to get inside a cloud to study it.

We do know, of course, that there are many different kinds of clouds. Those that generally yield the most rain—the steady downpour that soaks the earth or leaves windrows of snow along the garden wall—are associated with fronts. They are called stratiform clouds and they are created when one kind of air—warm and moist—rides up over a different kind—cooler and less moist.

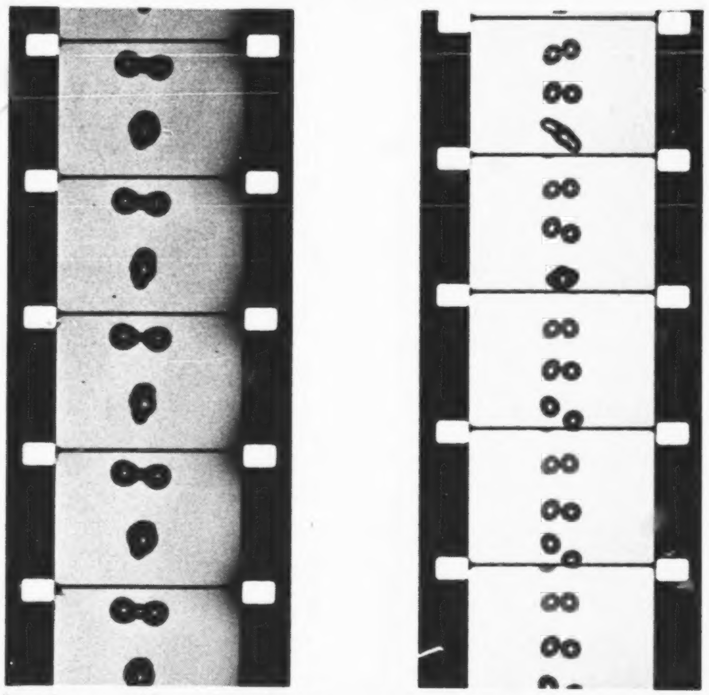
These stratiform clouds are the wispy cirrus, the first to appear as the storm approaches, then the thick and milky altostratus, and, finally, the low-flying "scud," the nimbostratus. Drifting overhead in order, they make up a cloud deck that may fill the sky for days.

But a deck of stratiform clouds can cover thousands of square miles. The clouds interact with each other in many, complex ways, and the interactions are hidden within the cloud system. Meteorologists have trouble just taking meaningful measurements in such a vast system, let alone making it yield its rain where and when they wish.

Away from the fronts, a different kind of cloud forms, the cumulus. It often stands alone, diamond-white against the deep blue sky. It looks soft and puffy like cotton candy, but on a summer afternoon it can explode into a giant thunderhead. Because cumulus clouds are often isolated, they can be simpler to observe and fly in than stratiform storms; therefore scientists have spent more time studying how to modify them than they have spent in research on modifying the stratiform clouds associated with fronts.



Researchers at Colorado State University prepare to launch a high-lift kite that will carry an air sampler, particle replicator, and other instruments up inside a storm cloud in the Rocky Mountains.



In an unusual experiment conducted at the National Center for Atmospheric Research, high speed film shows that water droplets under a slight electrical charge tend to coalesce when they collide, while . . . uncharged droplets touch but do not coalesce. This mechanism is a key element in the conversion of floating droplets to raindrops large enough to fall to earth.

With balloons, kites, and aircraft, they are "putting numbers on the atmosphere." They measure the ever-changing temperature, pressure, and humidity which determine a cloud's life cycle and measure the cloud motions and water or ice contained in the cloud. The investigation has often probed just how the small droplets comprising the cloud get collected together into large particles big enough to fall. This is a key question. The scientists want to know exactly how nature does it, and how they can help nature artificially.

Here's how cumulus clouds are formed.

In the morning, the sky is clear. The sun beats down and warms the soil, and the soil, in turn warms the air in contact with it. The warm air rises. As it rises, it expands, and as it expands, it cools, just as air cools when it is released from a tire.

Result: the relative humidity of the rising air increases; that is, it gets more and more saturated, less and less able to hold its moisture. If the air continues to rise, it will eventually become saturated and some of its water vapor will condense out in the form of cloud droplets. You have seen such droplets when you exhaled on a winter day.

The cloud droplets are numerous — thousands per cubic inch. They are very small — a billion of them together would not weigh an ounce — and have a negligible falling speed through the air. As the cloud ages and the upward motion in the turbulent cloud ceases, these droplets would mix into the surrounding drier air and evaporate.

To get rain, somehow a drop must be formed which is big enough to fall through its neighboring droplets and collide with some of them. Once it starts colliding and collecting droplets onto itself, it rapidly becomes larger, falls faster, and collects droplets more efficiently. It grows until it falls out of the cloud, and can be a large raindrop if the cloud is thick. It may have collected millions of cloud droplets onto itself during the fall.

One way the particle will grow to the critical size — a few thousandths of an inch — where it can continue growing by collisions is if it has formed on a large condensation nucleus. Condensation nuclei come from dust and salt, from many natural sources and from the byproducts of civilization — smoke, car exhaust, and other types of pollution.

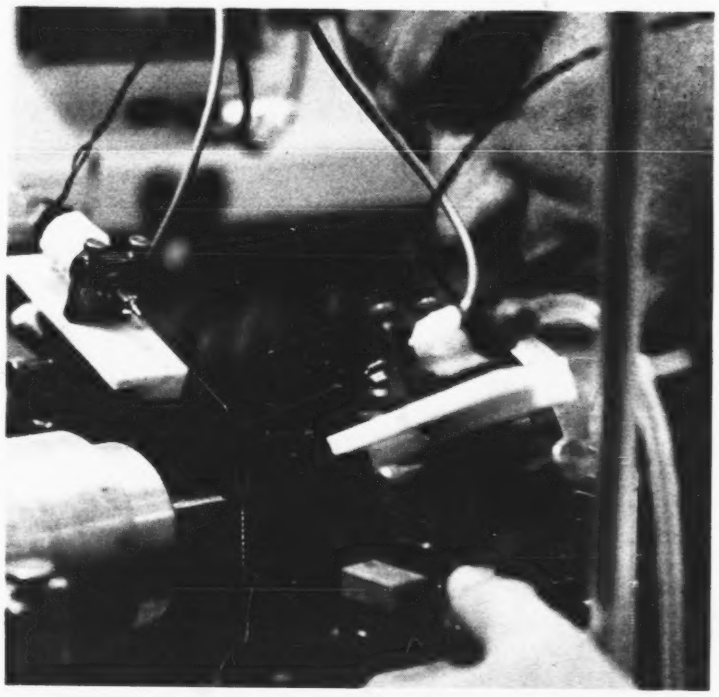
We are just beginning to learn what the natural and artificial sources of condensation nuclei are, and how their sizes and numbers affect the rainfall. More knowledge is needed before we can significantly increase rainfall by adding man-made condensation nuclei to the clouds.

An approach to rain making is to make the droplets start colliding more efficiently, so that particles do not need to grow so large before they can start the chain-reaction of growing by collisions. Scientists at the National Center for Atmospheric Research in Boulder, Colorado, are studying one of the mechanisms that apparently can do this: cloud electrification. In one experiment, they aim two streams of droplets at each other. The droplets do not coalesce, they bounce apart, apparently because of the thin layer of air trapped between them. But if the droplets are given a slight electric charge, they combine into one larger droplet when they collide.

But, again, scientists have much to learn before they can hope to increase rainfall by controlling electrification. Indeed, it may be impossible to control the electrification of a cloud at all.

But there is a much more important growth mechanism which gets particles up to the critical size where collisions become possible. It operates only in cold clouds, clouds which reach upward so high their tops are below freezing. It is a mechanism which is easy to control by cloud seeding, and so, since cold clouds are common, most cloud seeding involves this technique. It is the introduction of ice crystal nuclei.

The sequence of events in such cold clouds goes something like this. Again, air, heated from below, rises.



A technician adjusts the machine which produces water droplets and sends them along a collision course. Some collide and separate; others collide and coalesce, as shown in the picture at left.

These technicians are collecting samples of particles in the atmosphere with a specially equipped airplane. Some of the particles will serve as nuclei for tiny droplets which may later grow into raindrops.

As it expands, it cools and vapor condenses out as cloud droplets. As the vapor condenses, it releases the latent heat of evaporation, lifting the droplets higher still. Eventually, if conditions are right, they pass the freezing level.

But, by a quirk of nature, the droplets do not freeze. Because they are relatively pure, their temperature can be lowered to zero and below without freezing. In this state, the droplets are called super-cooled.

But suppose there are some ice crystal nuclei in these clouds — either natural nuclei, or silver iodide particles put up by a cloud seeder. Ice crystals grow rapidly on these nuclei, and quickly reach the critical size.

Like so many other elements of cloud physics, ice crystal formation is vastly complex. The size and shape of the nucleus affects the formation of the crystal. The temperature of the droplet and of the surrounding air is of critical importance. Work done by Dr. John Hallett, at Desert Research Institute in Reno, Nevada, shows that a difference of just one degree in temperature can vary the shape of a crystal dramatically. This explains why hexagonal plates of ice are found at certain altitudes while stellars, or stars, and columns and needles of ice are found at others.

But, back to the cloud.

Vapor has condensed to form droplets; the droplets have risen to such a high altitude they have become super-cooled. If ice crystal nuclei are present and are surrounded by super-cooled droplets, crystals grow rapidly. They take advantage of an instability in the atmosphere — the instability of super-cooled water.

The speed of growth in the ice mechanism is a result of nature exploiting the unstable condition. The vapor pressure of ice is less than the vapor pressure of water at the same temperature. Therefore, air in the cloud which is saturated with respect to the super-cooled drops is supersaturated with respect to ice. As a result, water molecules condense from the vapor onto the crystal, while evaporating from the surrounding droplets.

The ice crystal growth is very rapid. Dramatic footage in the film "Changing the Weather" shows this fast growth of ice crystals in the laboratory. The ice crystal will grow even starting from certain other crystals which somewhat resemble ice. Silver iodide is one example. It is the material which is widely used in cloud seeding. Certain natural dust particles act similarly. They are far more rare and far smaller than condensation nuclei.

Little smoke particles of silver iodide, or the special natural dust particles, once they get into a super-cooled cloud, can grow in less than a minute from their initial size of one millionth of an inch to an ice crystal of the critical size of a few thousandths of an inch. This crystal can then grow further by colliding with and collecting more droplets, and then melt to form a raindrop. Efficiently used, an ounce of silver iodide costing about a dollar can deliver millions of tons of rain.

The cold raindrops that plunge earthward from a summer thunderstorm in the United States have usually passed through the ice crystal phase sometime during their long and violent evolution.

How do scientists study the complex interrelationships between temperature, pressure and humidity that control droplet and raindrop formation?

To get their instruments inside a storm cloud, researchers at Colorado State University in Fort Collins, Colorado, use a huge kite shaped like an airplane wing. The largest model is said to provide enough lift to carry a Volkswagen into the sky, but the researchers send up more practical items such as an air sampler, a particle replicator; and temperature, pressure, and humidity meters.

The air sampler can be triggered from the ground to capture a parcel of air. Later, on the ground, the air is cooled in a chamber to simulate a parcel of air in a cloud, and ice crystals will appear. By counting these, the researchers can determine the number of effective ice crystal nuclei per known volume of air. This is an important element in weather modification; too many nuclei could **decrease** rainfall by dividing up the available water into more but smaller crystals.

The replicator captures snowflakes and crystals on a strip of soft film. When the film hardens, the shape of the crystal is captured permanently, to be studied at leisure.

The advantage of the kite is that it can be set to fly at one altitude over one location and can thus continually monitor events in one place over a long period of time. As one researcher put it, "The kite just sits there and watches the storm go by."

But can scientists actually modify clouds? Can they make them give up rain or snow at will?

Dr. Vincent J. Schaefer at the Atmospheric Sciences Research Center discovered one method. In 1946, he and Dr. Irving Langmuir "seeded" a stratiform cloud with pellets of dry ice. The ice cooled the cloud droplets so much they formed ice crystals even though no freezing nuclei were present. The crystals fell to earth as snow, leaving a gaping hole in the cloud deck.

But such small stratiform clouds contain so little moisture it is not worth seeding them if you are after rainfall. Potentially more fruitful are the cumulus clouds and winter storms. In some experiments, cumulus clouds have been "seeded" with silver iodide particles, providing extra ice crystal nuclei. How successful have they been?

A recent study by the National Academy of Sciences shows that rainfall from cumulus clouds can be increased about 10 to 20 per cent. In winter storms, precipitation increases of about 10 per cent "apparently" result from seeding.

So, the seed has been planted. But much research must still be conducted: What is the drop size spectrum in a natural cloud? What is the velocity of vertical currents and how do these currents affect droplet formation? What is the temperature, pressure, and humidity distribution throughout the whole cloud? What is the actual water content?

Even more research, over a greater period of time must be carried out before whole storms can be modified. And we may never see the day when man can control the climate of a large area.

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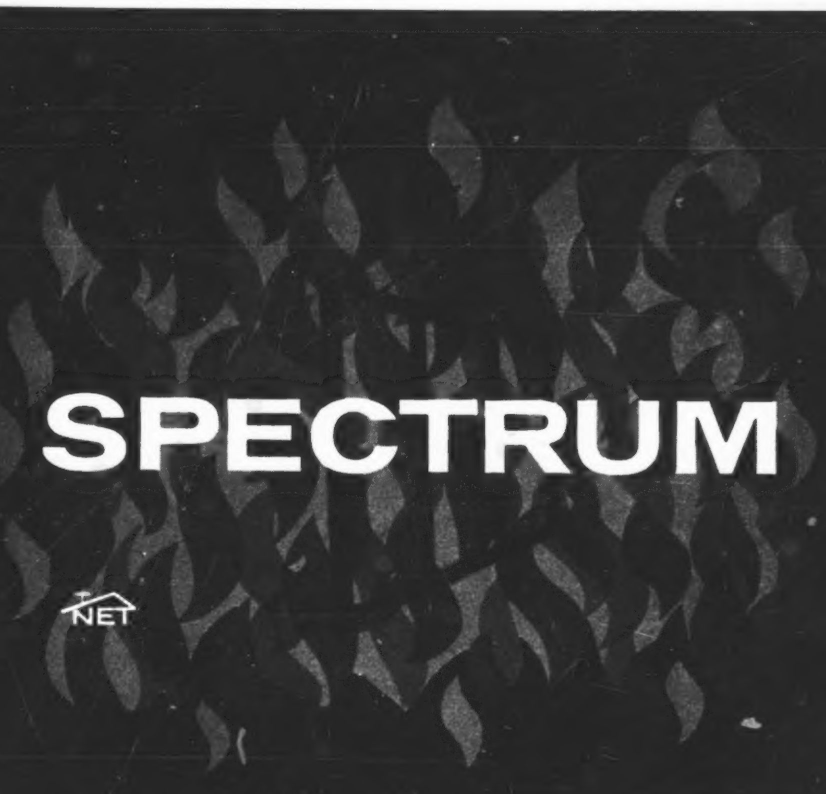

SPECTRUM

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THE TREMBLING EARTH

Each year more than 100 major earthquakes shake the earth. Earthquakes are one of the most awesome natural causes of human disaster; some causing loss of life running into the thousands and property damage amounting to many millions of dollars.

Today, although we still cannot predict exactly when or where an earthquake will occur, we are beginning to understand the forces that cause these gigantic earth ruptures. Scientists in countries around the globe operate seismic stations, to measure the waves produced by earthquakes. By recording and analyzing these waves, the seismologists hope to unlock the secrets of "The Trembling Earth."

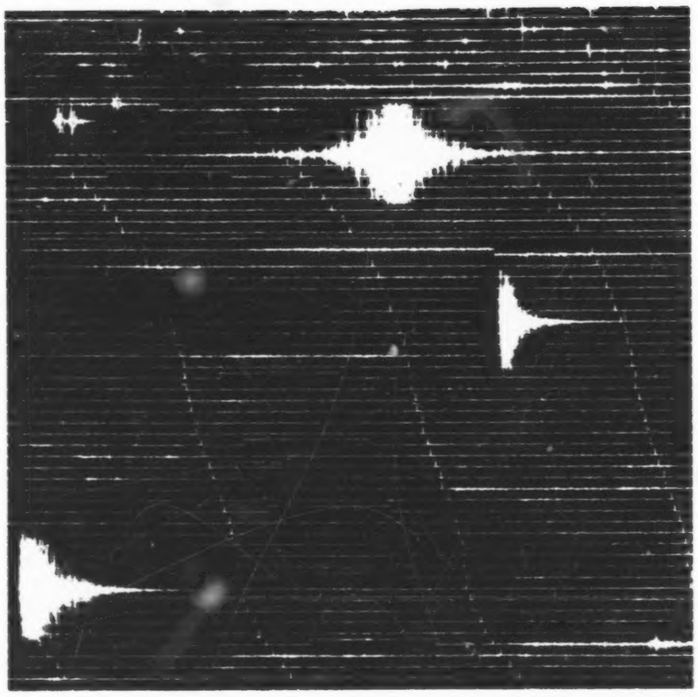
Dr. Jack Oliver is chief seismologist at the Lamont Geological Observatory of Columbia University. One of the observatory's principal seismic stations, in the northeastern part of the United States, is located 1850 feet under the ground in a mine at Ogdensburg, New Jersey. This remote location is necessary since the instrumentation used to detect and study movements of the earth is so delicate that a single light footstep 100 feet away can disturb it. Even the temperature and atmospheric pressure are kept as constant as possible to avoid disturbing the hypersensitive equipment.

Dr. Oliver and his colleagues are seeking a basic understanding of earth structure and major geological processes; and specifically, they are learning about earthquakes, and how to predict them.

Dr. Oliver's station must be able to detect seismic waves which come from distant earthquakes, waves which travel through the entire globe. To record these waves, his instruments are installed directly in the hard bedrock of the earth's crust. "Even this rock isn't as solid as it might seem," Dr. Oliver notes. "When seismic waves come through here, the rock actually vibrates." And it's these vibrations that are recorded.

The seismic waves come into the station as a complex wave pattern composed of many frequencies. To discover the location and size of the event they represent, the waves must be unscrambled and interpreted. This is done by recording simultaneously on several different kinds of instruments.

In the array of more than twenty different monitoring instruments in Dr. Oliver's station, the basic device for detecting distant earthquakes is the inertial seismometer. This consists of a pendulum suspended between two magnets. When a seismic wave from a distant quake moves the earth's crust, the base of the instrument is disturbed.



This is a partial record of one-day's micro-earthquake activity at the Denali fault, in Alaska. The micro-earthquakes can be distinguished from background noise by their abrupt beginnings. This record was made by a portable field seismometer, an instrument that measures the vertical component of ground motion.

Dr. Jack Oliver (left) confers with George Hade, an instrumentation engineer at Lamont Geological Observatory of Columbia University in front of the entrance to the New Jersey Zinc Co. mine where their seismic station is located. The station itself is 1850 feet under the ground.

But the pendulum, due to its inertia, tends to remain steady. This difference in movement generates a small electric current which is amplified and recorded.

The first waves to arrive from an earthquake are in the high frequency range. Later, longer waves are recorded in the low frequencies. The distance and direction of the earthquake can be found by analyzing the arrival time of these long and short waves, and the directional set of the instruments.

Some of the records of seismic waves, made on photographic paper, are routinely exchanged with those of other, similar stations throughout the world. The recordings show some seismic waves which have traversed the crust of the earth, and others reveal waves which have actually penetrated the earth's deep interior. In this sense, the seismologist X-Rays the internal structure of our world.

One of the newest and most sensitive instruments in seismology is the strain seismograph. It's designed to measure minute changes in the length of a portion of the earth's crust. There are four such instruments in Dr. Oliver's station, each oriented in a different direction. The heart of this device is a rigid quartz tube, two-inches in diameter and two-hundred-feet long. At one end it is anchored solidly to the bedrock. Throughout its length, the tube is carefully aligned and suspended by slings of delicate stainless steel wires.

At the free end of the rod a transducer alters a small electric current when the rod moves. This current, when amplified is a record of the relative motion of the bedrock at the two ends of the tube.

It's difficult to realize just how sensitive this instrument is, but as an example; the tube aligned toward the Atlantic Ocean actually records the depression of the edge of the continent by the weight of the sea as the ocean comes in.

The strain seismograph detects some of the longest waves in the earth's crust. It keeps a record of "earthtides," similar to ocean tides, which show how the whole crust of the earth slowly rises and falls in response to the gravitational attraction of the sun and the moon. At the mine, "earthtides" as large as ten centimeters have been recorded.

The instrument also, of course, records earthquakes. According to Dr. Oliver, some evidence has been found of a direct correlation between earthtides and earthquake activity. If such a correlation can be established, earthtide records, which supplement our basic seismic data, could offer a whole new possibility for accurate earthquake prediction.

One of Dr. Oliver's primary objectives is, of course, understanding the basic forces that cause earthquakes. In the laboratory at Columbia University studies are made using special gelatin models which are viewed through polaroid lenses.

Dr. Oliver explains:

"Earthquakes may be thought of as the result of the warping and rupture of the earth in response to geological forces. As the layers of the crust are distorted, strain patterns develop. When the critical point is reached, a violent rupture occurs.

"Such a rupture, which normally occurs along a pre-existing zone of weakness, is the immediate cause of earthquakes. It is along such a "fault" that subsequent earthquakes are most likely to occur."

The most dramatic example of this process in the United States can be seen in the San Andreas fault which stretches diagonally across California from the Mexican border to north of San Francisco . . . a total length of over 500 miles. Because it cuts through several well-populated areas, the fault is closely monitored by seismologists from many educational institutions and government agencies.

The San Andreas fault shows a horizontal displacement of as much as 150 miles. This movement took many earth-

Dr. Oliver and Hade check seismic records obtained in Lamont's underground seismic station in New Jersey. By analyzing the data obtained here, geologists can check on earthquake activity anywhere in the world.

A river of ice covers this segment of the Denali fault in Alaska. Faults like the Denali are closely studied by seismologists who are searching for the key to the cause of earthquake activity.

quakes, and more than 60-million-years to take place. In recent times, parts of the fault have shifted as much as 21 feet in a single quake.

"Faults can be found anywhere in the world, and an earthquake is possible just about anywhere." While scientists cannot yet precisely predict an earthquake, they do know that the infrequent large and potentially destructive earthquakes, and the more numerous small ones are to be expected along active faults such as the San Andreas.

Another highly active earthquake zone is along the great Denali fault in Alaska.

Dr. Oliver sent a team of young seismologists to take readings along part of the thousand-mile rupture.

"Alaska has more earthquakes than any other state. We chose the Denali because it is highly active, and largely unexplored. Even here, however, large earthquakes are not frequent, but small ones are more numerous. We wanted to study micro-earthquakes which are the smallest and most abundant of all.

"In our micro-earthquake program we wanted to get a profile of seismic activity along the Denali, and to try to study the relationship of micro-earthquakes to great ones."

Micro-earthquakes are a puzzle to seismologists. They know that whenever there are large earthquakes and aftershocks, there are great numbers of micro-earthquakes. They might only be the trailing echoes of a big event, but some could be warning signs of impending major activity, and provide a way to predict large quakes.

During the field study in Alaska the seismic instruments recorded a wide variety of events, even an occasional bear or moose walking by. The information gathered on micro-earthquakes was invaluable; some days in one area as many as ten thousand events were recorded. Later, following the Denali fault westward, the scientists studied seismic activity near Mt. McKinley, the highest peak in North America. "The same geological forces which built these mountains, ruptured the earth . . . creating the whole related system of faults which made Alaska 'earthquake country.' "

Dr. Oliver recorded the great Alaskan earthquake of March 27, 1964, and recreates the event:

"I remember it as one of the most violent I've ever recorded. Back then at Lamont in 1964, we had just begun to supplement our conventional records with magnetic tape, so we can play back the event today.

"Every seismologist in the world remembers that fateful March 27th. Our seismographs had been quiet all day. They gave no warning of impending seismic activity three thousand miles across the continent.

"At our laboratory in the mine it took about eight minutes for the earthquake's first seismic waves to arrive. It was a huge earthquake. The first waves to arrive had traveled from Alaska through the interior of the earth. . . . Minutes later, our seismometers went wild with immense waves which had traveled along the earth's surface. At times, the bedrock in the mine actually rose and fell about a centimeter. The surface waves were to continue for many hours.

"They drove our instruments off scale, and temporarily disabled many of them.

"When an earthquake is recorded, we can locate it by measuring the arrival times of the first series of seismic waves. By comparing these arrival times with known values, we can estimate the distance to the earthquake. By analyzing the data from three different seismographs, which record the three components of ground motion, we can deduce the location of an earthquake anywhere on the globe.

"In the case of the Alaskan earthquake, we had many opportunities to check our measurements. The main quake on Good Friday was followed by a long series of aftershocks, both large and small. Our seismographs were kept busy through the night."

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The abundance of these aftershocks gave Dr. Oliver and his colleagues much information about the nature of the main quake. From the data gathered, they could deduce the extent of the rupturing and learn something about the geologic processes responsible for the main shock. The large aftershocks continued for many months, as they do after all large quakes. Smaller but detectable aftershocks related to the Alaskan disaster continued for many years.

"For us," Dr. Oliver explains, "each big earthquake underlines the immediate importance and urgency of our seismological studies. Our instruments are kept running day and night to collect all the data which will further our knowledge of earthquakes, and the earth itself.

"This is a time in seismology when all our data is beginning to add up.

"We already know where earthquakes are most likely to occur, and we even know approximately how often they'll occur. As our understanding of the earthquake mechanism grows, we feel each day we're getting closer to a method for precise earthquake prediction."

Dr. Oliver also has hopes that in the future we might find ways to prevent some earthquakes. "A further understanding of the faulting mechanism is required. But it has even been proposed that we could learn how to drill down into a fault, and pump water into it in an attempt to relieve the strains which are the immediate cause of quakes."

But to develop methods for earthquake prediction and other ways to minimize the earthquake hazard for man, we must first understand geologic processes on a global scale.

Dr. Oliver's studies, and those in other fields, reveal a global network of related fractures. "The pattern seems to reflect major geologic forces which are causing the ocean floor to spread and the continents to drift apart.

We have only just begun to comprehend these processes. But our data, and that from many different fields of geophysics, is beginning to add up. It seems we're on the verge of understanding for the first time, not earthquakes alone, but the major geological forces which have shaped the earth on which we live."

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STOP OR GO - AN EXPERIMENT IN GENETICS

Dr. Theodosius Dobzhansky in a book called "Heredity and the Nature of Man" stated: "Among the many advances of science in our age, the development of genetics, the science of heredity, is one of the most impressive ones. To be sure, genetics has not invented a new kind of superbomb, nor can it match the romantic appeal of interplanetary travel. The interest and importance of gentics are in a different realm. More than two millenia ago, Greek sages discovered that to "Know Thyself" is the foundation of all wisdom." One of the ways that we can know ourselves is to understand the factors that govern heredity.

Like all living things the human being is made up of cells. Inside the nucleus of each of these cells are the units of matter that govern heredity which we call genes. The only visible evidence of these genes are long thin strands of matter that can sometimes be photographed with the electron microscope at magnifications of hundreds of thousands of times. Stretched out along these thin strands is an invisible chemical language of heredity that has been called the language of life.

This language spells out the genetic differences between individual human beings, and the differences between the multitude of other living things on earth. It also spells out the similarities between creatures within a particular species that are handed down from generation to generation. One of the most profound ways that we can know ourselves is to understand the language of life.

The reward for reaching down into this invisible world and for reading the genetic language is to have the ability to literally change man for the better—by controlling or eliminating inherited diseases or other undesirable traits.

The fascination in this language is in a compact, rapid, accurate, universal system of coding by which a relatively simple system of four chemical words is translated into the millions of forms of life found on earth.

The way to get at this language and decipher it is to perform experiments in the genetics laboratory such as the experiment shown in this film. Experiments in genetics in the last thirty years have resulted in one of the most exciting, important and awe-inspiring breakthroughs in the history of science.

In 1944, geneticists O. T. Avery, C. M. MacLoed and M. McCarty confirmed the fact that hereditary characteristics were transferred from one strain of bacteria to another in a nucleic acid called DNA. This DNA had the ability to control the chemical reactions and the growth of the bacteria. The DNA also seemed to have the ability to make exact copies of itself, and thus to pass on to other generations the chemical instructions it contained.

In 1953, J. D. Watson and F. H. C. Crick envisioned how the component parts of DNA were put together. The Watson-Crick model, which was later experimentally confirmed, showed that DNA contained a long spiral ladder of chemical "rungs," or letters in the genetic alphabet. These "rungs" were made up of one of four chemicals: Adenine, Thymine, Guanine, and Cystosine, which were repeated in different combinations over and over again, millions of times in different sequences, for different sets of instructions. Genes are simply long sections of the ladder-like structure of DNA that carry specific genetic information. The ability of DNA to reproduce exact copies of itself was explained by a mechanical template mechanism that reproduces all the precise sequences of chemical letters. DNA also makes other exact copies of itself that carry out its work outside the nucleus of the cell called RNA.

Heredity is coded in the four letters in much the same way that far simpler messages are coded in the two letter system of dots and dashes of the Morse code. There are 64 possible combinations of the four letters taken three at a time. The meaning of most of these three letter words is now known. One or more stand for each of the amino acids which go into the productions of the many different proteins necessary for life's diverse processes.

In the words of George and Muriel Beadle in their book, "The Language of Life": What has happened in genetics in the past decade has been the discovery of a Rosetta Stone. The unknown language was the "molecular one of DNA. Science can now translate at least a few messages written in DNA-ese into the chemical language of blood and bone and nerves and muscle. One might also say that the deciphering of the DNA code has revealed our possession of a language much older than hieroglyphics, a language as old as life itself, a language that is the most living language of all—even if its letters are invisible and its words are buried deep in the cells of our bodies."

While the meaning of many of the words, in terms of the amino acids they stand for is known, the long billion word sentences still remain to be read. There are a number of mysteries in the reading of the sentences; for example, punctuation marks. In any language there are, in addition to words, symbols that say when or how to stop or start reading the next word, sentence, paragraph or message. Geneticists therefore had reason to believe that the language of the genetic code similarly contained punctuation marks and set out to find them. The search is still going on, for these are difficult problems. They are also important problems, because many of the secrets of normal or abnormal growth might be hidden in misplaced or misread punctuation marks.

Among the geneticists probing these secrets is Dr. Norton D. Zinder, who is a professor on the staff of The Rockefeller University. In the film "Stop or Go—An Experiment in Genetics" we have taken one of his experiments to stand for the numerous experiments being performed in the many research laboratories throughout the world. We hope that a detailed view of this experiment would give some insight into the problem of punctuation marks in the language of life and additional insight into the problems of genetics research. How do punctuation marks work? How can they be investigated? How does science itself operate? To answer these questions it is necessary to first know something about the science of genetics.

Dr. Norton D. Zinder discussing his research into the f2 viruses.

Genetics deals with the inborn or inherited traits of living organisms. The most interesting and important organism is, of course, the human being. It is very difficult, however, to experiment with and to investigate the many complex inherited qualities in human beings. In addition, it would take many years to study just a few generations. Taking advantage of the fact that all living things on earth—plants, mice, elephants, birds, fish—are related and that they are constructed along the same fundamental lines with the same fundamental building blocks and building materials, scientists can study simpler organisms that multiply rapidly and learn more about complex organisms like human beings that do not.

The bacteria used in Dr. Zinder's lab are common E Coli bacteria which are found in the intestines of human beings and in sewage systems in most parts of the world. But in addition to bacteria, Dr. Zinder makes use of a virus that he has discovered, called the f2 virus. The f2 virus is a parasite that grows inside bacteria. Most of its life work is performed by the host bacteria, and f2, therefore, can get along in life as a very simple organism. It is the simplest and the smallest known self-replicating organism on earth. It is also the most prolific. One virus produces close to twenty thousand offspring in an hour, and as a result there are more f2 viruses in the world

Niyati Yodh, laboratory assistant, looking for evidence of the mutant f2 virus.

than all other organisms combined.

The life story of the virus is quite simple. The virus fastens itself to the hairs of a bacteria. It then shoots its RNA into the bacteria. Once inside, the RNA directs the making of the structure of the virus called coat protein. The RNA then directs the making of more RNA inside the bacteria, and the new RNA in turn makes more coat protein. As the process is rapidly repeated, the viruses multiply and use up the resources of the bacteria, until finally the bacteria is literally consumed by millions of viruses. The viruses then go out to find more bacteria to devour, and the story is repeated over and over again.

While the human being has billions of genes containing genetic information for billions of life processes, the bacteria, a one-celled organism, gets by with thousands of genes, and the f2 virus with just three known genes. One of the genes has to do with the ability of the virus to enter the bacteria, the second with the making of more viral RNA, and the third with the making of the structural material of the virus, called its **coat protein.** Because the f2 virus has just three genes, or three information systems for three life processes, it is possible to isololate and study the functioning of each individual gene. This would not be possible in more complex organisms. The gene connected with the production of coat protein is studied in the experiment in our film.

Investigations in contemporary genetics can be divided into two general groups of experiments. The first, in classical genetics, involves the study of the inherited similarities and differences in a number of generations of living organisms. Changes or mutations are introduced and the results of these mutations are studied in future generations. The second group of experiments are test tube experiments in which an attempt is made to take the events that occur in more or less a natural life environment and duplicate them in the environment of the test tube. In the test tube, events can be dealt with more precisely and the inner mechanisms studied in detail. The production of protein can be studied and even the behavior of individual molecules. This kind of investigation is called molecular biology.

Experiments that probe the secrets of the genetic code can make use of both types of investigations which scientists call "in vivo" or "in vitro": in life or in the test tube. The experiments in life suggest experiments in the test tube.

So much for the general science of genetics. Our experiment begins as experiments most often begin, with the results of other experiments that have preceded them. Dr. Zinder was interested in a report from another lab that a strange mutant virus did not grow and multiply in a particular strain of bacteria, while it would multiply in other strains. The mutant virus would evidently send its genetic material into the non-permissive bacteria, but no new viruses were formed. The tentative explanation for this unusual event was that the mutant virus was not making its coat protein in the bacteria. The assumption was that in the non-permissive bacteria a genetic word for stop was being introduced in the middle of the coat protein gene of the mutant virus. Dr. Zinder hoped to confirm experimentally these reports with a mutant of his own f2 virus and to try to determine how the word for go in one organism could possibly mean stop in another. The amino acid sequence of the coat protein gene was known. What was not known was where and how a change was taking place in that sequence.

Mutants will occur in nature by chance, and this is largely the way that evolution takes place and accounts for the large variety of creatures on earth. But this is a long, slow process. The way to speed up the process of change through mutation is to use X-rays or chemicals called mutagens which geneticists have discovered affect genes like X-rays. Dr. Zinder makes use of a mutagen called nitrous acid to produce mutants of his f2 viruses. One mutant would probably occur naturally in hundreds of thousands of viruses. The nitrous acid speeds up the process and produces one mutant perhaps in a thousand.

It is still a difficult job to find the one mutant in a thousand. The way to find it is to screen patiently hundreds of the treated. viruses, first in the non-permissive bacteria and then in the normal permissive bacteria. Dr. Zinder and his associates were able to find the mutant they were looking for and infer that it was a mutant in the coat protein. They were then able to grow them in large quantities.

To understand the events that were taking place inside the bacteria, Dr. Zinder then decided to try to duplicate the events in test tubes. It was necessary to get pure RNA from both the mutant and normal f2 virus. This was accomplished in a long number of steps involving physical separation techniques such as centrifugation and then the use of chemical extracts combined with centrifugation. In a step called "incorporation," the pure RNA of both the mutant and the normal virus are added to an extract of bacteria, pep and food agents, buffers, amino acids and a radioactive tag. Through the radioactive counting that followed, it was possible to say definitely that a great deal of coat protein was being grown in the test tube by the RNA of normal virus, but very little complete coat protein by the RNA of the mutant virus. The protein production of the mutant and normal RNA was put to further tests in a device called a Sephadex column. In this column small Sephadex beads either trap and slow down small proteins in the passageways in the beads, or permit slightly larger proteins to go around them by a much quicker route to the bottom. When a sample is placed in the tube it contains a number of different sized proteins. As the proteins go through the Sephadex beads, some enter the beads and are slowed, and some are not. At the bottom of the tube the large proteins come through first, then the smaller proteins. It is then possible to separate the small from the large proteins and analyze in detail the kinds of protein that have been produced in the test tube. These column tests revealed that the mutant virus, while it was not making full coat protein, was in fact making a small fragment of its coat protein in the non-permissive bacteria. From this it was possible to determine that a stop signal had been introduced in the gene of the virus for making coat protein, and it was also possible to tell where the stop signal had been misplaced. There was a change in the sixth amino acid after the start signal in the gene for coat protein. The change was in one letter of the three-letter code, from CAG, the code for glutamine, to UAG, which is a stop signal.

Finally, Dr. Zinder was able to adjust the chemical composition of the extract from the non-permissive bacteria in the test tube so that it would now allow the mutant RNA to make as much coat protein as the normal RNA of the virus. Dr. Zinder and other geneticists now knew more about the nature of stop signs in the genes of viruses and more about stop signs in all organisms. An important step was successfully taken in the unravelling of part of the genetic code. But beyond the results of the experiment, important as they are, the way in which the experiment was carried out is perhaps of equal importance. What society wants from science are results that ultimately give rise to a product or a service that will benefit mankind. Certainly the results of experiments in genetics will eventually lead to human benefits, but science has more to offer. Science offers the world a method for examining itself. It offers society an example of cooperative effort that is a model for other forms of human endeavor, an example of an historical approach in which knoweldge can be cumulative and progress can be measured.

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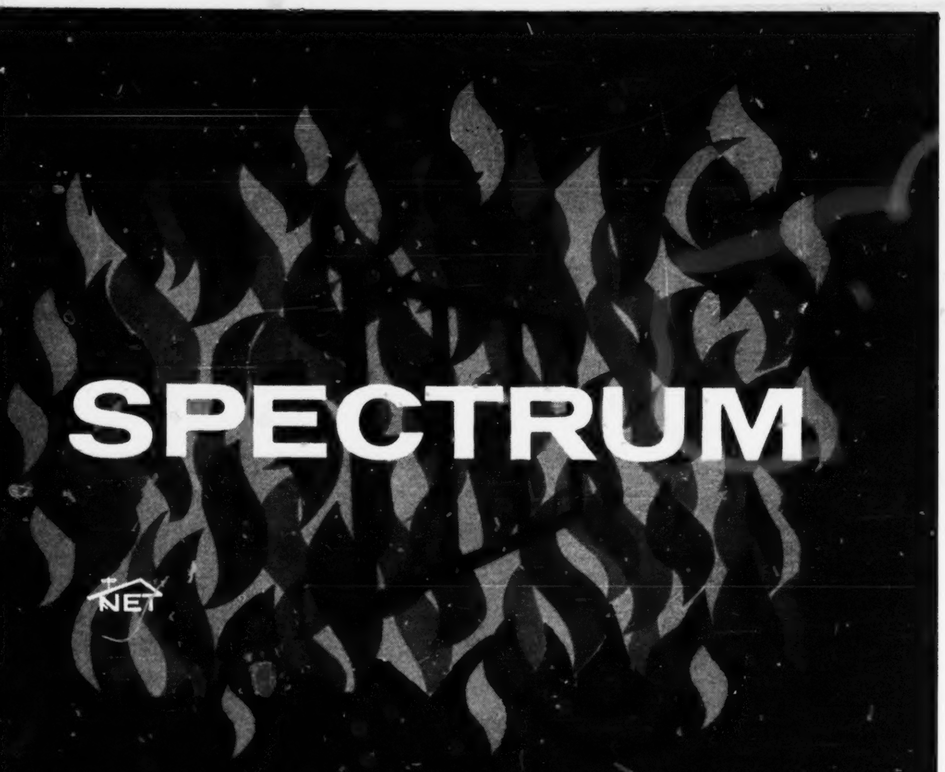

SPECTRUM

A VISIT WITH HAROLD UREY

In 1934, Dr. Harold Clayton Urey was awarded the Nobel Prize in chemistry for his discovery of deuterium, or heavy hydrogen. An important factor in nuclear research, Dr. Urey's discovery has been called one of the foremost achievements in modern science. During World War II, he helped the United States develop the atomic bomb. Since then his wide-ranging studies have extended the geophysics of the solid earth, through geo-chemistry, to the origin of meteorites and the solar system.

This then, is Harold Urey . . . chemist, physicist, creative thinker and teacher. He is one of the world's most noted scientists, and, with the zeal of a missionary and the spirit of the Crusader, he has, throughout his long career, exemplified the adventure and excitement of science.

At the age of 74, Dr. Urey is a professor-at-large of chemistry at the University of California. He spends much of his time at the University's San Diego campus, where he continues to mix classroom teaching with pure research. Recently he was asked to discuss the major influences and decisions that affected his life and some of the conclusions he has reached about science and the world we live in.

ON THE ATOMIC BOMB

"I do not feel any guilt at all about having helped invent the bomb. You see, in the war we all become involved . . . scientists, soldiers in the field, the housewife who economizes in various ways . . . we are all involved in it. And, of course, when it came to the hydrogen and atomic bombs, they were being studied in Germany, and the Russians were interested. If the scientists in this country had not worked on this bomb, somebody else would have. There was no possibility of stopping work of this kind. Of course, when the war was over, I got out of the weapon business immediately. It doesn't interest me as a thing to devote my life to. There are people who are interested in it, and I have never taken the point of view that it should not be done, because I do not believe that we could have possibly gone into the years after the war without maintaining our position with respect to these things."

Dr. Urey was asked if he had given any thought to controlling nuclear weapons, and replied:

"Well, of course the problem is political. If we had a world government that had the power to make laws, to conduct trials, to mete out punishment; a law against the manufacture of atomic weapons or the conspiring to make atomic weapons could be passed and it could quite easily be policed . . . and it is my belief that unless something of this sort is done, the time will come when some

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Dr. Harold Clayton Urey, Nobel laureate, and professor-at-large of chemistry, University of California.

Dr. Urey is shown on the La Jolla campus, being interviewed by NET science editor David Prowitt.

person like Hitler gets into a government somewhere and he starts the whole thing going and just as soon as the first person, the first country, throws an atomic bomb, then we're all immediately in trouble.

"At the present time, it is completely impossible (to form such a government). The Soviet Union would not join a world government that had real sovereignty and the western democracies wouldn't either. I have thought that the first step . . . to be made is organization of a democratic government of the Western democracies who understand what we mean by a government, who subscribe to a bill of rights essentially and know what we mean by representative government."

ON U.S. EDUCATION

"It often seems to me that we Americans exhibit a great respect for education and very little respect for teachers. Teachers are often very poorly paid, although better today than a few years ago, and are often held in low esteem. Too many people feel that if teachers had any real ability they would be doing something . . . anything . . . else. It does not seem to bother anybody that, to make a little extra money, a teacher has to fill up your gas tank on Saturdays.

"Well, it bothers me. Teachers at all levels must be paid well and we must respect learning. Actually, teachers along with intellectuals, are regarded with suspicion today. The population of this country seems to have a predilection for trusting essentially stupid people, I think, at times, and mistrusting those who are brilliant. This attitude should be changed or we will rapidly fall behind in the difficult subjects of the sciences as well as any other intellectual pursuit."

ON SOVIET EDUCATION

"Whatever the faults of the Soviet Union may be, its people have a great respect for their scientists and intellectuals. The Soviet Union started out fifty years ago with an illiterate population that has become literate to a large extent. Russia has become the second power, military power, of the world. You don't get that without education. It has become our only competitor in the space program. You do not get that without very good education, especially in the sciences. And you might pay attention to this! The Russians pay their students to go to college. It is not just a matter of tuition, they pay all of their living expenses too . . . regardless of their background or economic needs. I think it might be a good idea to imitate some of the things the Russians do if we want to compete with them. That is my opinion. We should not always see everything that they do as bad."

ON THE U.S. SPACE PROGRAM

"I could see no practical or commercial advantage to going to the moon or any of the planets. But, I don't think it makes any difference whether I think it is worthwhile or not. When men get to a place where they can go to the moon, someone is going to go to the moon just because it is there. It's as simple as that. It is just in the nature of man. Of course, there is also the element of national prestige. But, primarily, our space program is a great adventure."

ON THE ORIGIN OF THE MOON

"My theories on the moon are not so definitely proven. In fact, any theory of the moon does not have sufficient facts to support its point of view to make it generally accepted. I also do not regard my ideas or hypothesis, in regard to the moon, as being highly certain at all. And this is true of a great many other things. Now, for example, a great many people believe that the moon was captured by the earth. I believe it is a reasonable hypothesis . . . that there might have been many moons around at that time. So that at least there is some possibility that one moon would be captured by one terrestrial

Dr. Urey at work in one of his laboratories.

planet. But, of course, it is very difficult to be certain about these things."

ON LIFE ON OTHER PLANETS

"We probably will not find any. But it will be exciting to find out. The mere possibility of the existence of life on another planet is of profound significance to biology. We already know that Venus is too hot for life to exist. Now if we were to find life of any form on Mars, whether it be bacteria or very simple organisms, it would be the most exciting thing imaginable for all of science. In spite of the fact that a considerable body of observational evidence supports the contention that some living organisms do exist on Mars, it will require close inspection before it is possible to verify the hypothesis and to determine the relationship between such living organisms that may be found and the terrestrial ones (that we might bring with us). Of course, there is always the possibility of contamination to contend with.

"Micro-organisms have a capacity to get into all sorts of curious places. We are learning that as we try to sterilize our space vehicle. To sterilize any instrument so that you're absolutely sure there is no bacteria on it is quite a task. To get the probability down to just one in ten thousand is exceedingly difficult; they will creep in somewhere, somehow. So the great problem of deciding whether there are any living micro-organisms on Mars or on the moon is to make sure you have not brought them with you.

"There would, of course, have to be some water on Mars for life to exist. The first thing we would look for, providing we do find life there, is the replicating mechanism of that life (that is the thing that provides the ability to reproduce). Is it the same as it is on earth, or is it due to something else? What a perfectly fascinating discovery it would be to find that Martian cells have another form, another way, of reproducing on Mars."

Despite a full schedule of teaching and research, Dr. Urey finds time to work in his garden.

ON WINNING THE NOBEL PRIZE

"There was a desperate feeling. I thought, how do you live up to it? How will I ever manage to live up to such a reputation? It really worried me tremendously, especially since it was entirely, in a way, accidental that we discovered heavy hydrogen. It was a discovery that was made on a prediction that was based on two mistakes . . . one cancelling out the other so that our result turned out to be correct. Whenever my hat gets a little tight, I think of that.

"Actually, there is always a lot of luck involved in scientific things, but I was much younger then and I thought, what if I go along and am not able to do any outstanding work after this? Is it not better never to receive an award than to get it and then fail to live up to the reputation? That was a long time ago. I feel I have not done too badly."

For Dr. Harold Clayton Urey, the pursuit of science is not so much a profession as a way of life. Dividing his time between the lecture room and the laboratory, this elder statesman of science continues his work as teacher to his students and advisor to his colleagues. In Dr. Urey's words:

"One of the greatest rewards of all is recognition by one's colleagues. There exists a fellowship among all true scientists that binds us together with an overwhelming devotion to learn the truth about these unknown things in nature.

"It is given to very few of us to make truly revolutionary discoveries, but it is given to many of us to contribute something and to be a part of the grand march of scientific knowledge. The most exciting thing about science is that the future always holds something new . . . something more fascinating, more unexpected than the past or present. We are constantly opening new vistas and these will be explored."

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Urey, Harold C., **The Planets,** Yale University Press, 1952.

Appendix C

Selected Comments from the Mail Questionnaire

Selected Comments -- "Exploring the Universe"

"The film clip showing the optical and radio solar features on the rotating sun was very well done. Is there any way in which I can get a copy of this segment of the film to use in class? The visualization of the concept of interferometry I thought was poorly done. The diagrams were too cluttered to convey easily the essentially simple concept that is involved."

"Well-planned, made, and delivered; understandable."

"For the layman, a bit too involved in parts."

"Good to see how astronomers work and what they do."

"The narration was good, at times too technical for the average person."

"The animation was good but the relevance to a better understanding of matter and energy should have been developed to a greater extent."

"As a science teacher, I found the presentation most appropriate. I feel, however, that the average layman would find the vocabulary and the concepts too obscure."

"Presented in an interesting manner, and not difficult to follow."

"Combining subtle humor with good science is all too rarely seen--it was excellent throughout the show."

"Clear, concise explanations--time lapse of radio and optical images excellent."

"I feel the public would have missed spectral analysis understanding."

"The scientists spoke much too rapidly using unexplained terminology."

"Information to layman about radio and optical telescopes, spectra, quasars and galaxies, good photographs of telescopes. Narration was good."

"The students who saw and heard the program said they felt that it was of too low a level to be of interest to college students."

"It should have been quite entertaining for the lay person, informative for those of greater background."

"I felt the program excellent, interesting, and informative and would have excellent value for my earth science class."

"For the average person, the program would be boring. As a teacher, the program and all Spectrum programs are interesting to me."

"I think this was deceptive in that it gave no indication of the large background in math and physics necessary. It made it all look too easy."

"My wife and I viewed this program from quite different scientific backgrounds. We both felt that it was well done and brought great benefit to the average viewer."

"On the whole, I thought the program was excellent. It was better than the BBC-NET on astronomy which was too long and over-dramatized."

"Some difficult points such as the interferometer were handled well but might have been clearer with the use of better visual aids."

"For the lay person the technical terms used were not explained and the narrator may have spoken a little too fast."

""The narration was spotty and variable--going from technical jargon to strange oversimplifications."

"A more dynamic speaker should have been found."

"A person seeing this would only be left with the fact that the experiments exist and almost nothing about how they are done and what results have been achieved."

"Objectives of scientific research were so warped as to be more misleading than informative."

Selected Comments -- "Changing the Weather"

"More development of ideas of experts. Perhaps fewer should have been used with more time for each."

"Well done for a person with some degree of curiosity for the subject, but it would have driven many other viewers to other channels."

"The various methods of gathering weather data should have been of interest to the general public."

"It was well edited and directed from the technical communications or media standpoint."

"Too much emphasis on instruments and manipulation of them. Little is learned from watching people watch dials. Descriptions of cloud formation air currents excellent."

"Average students would have difficulty comprehending the material without previous explanation, However, the high ability student should not have this difficulty."

"Excellent documentation, but unfortunately it was quite dull."

"I loved it--assigned it for homework--kids liked it too."

"The narrator was too "lectury" for public presentation."

"Laymen said that it presented little that they had not already read in the news. Perhaps to the less sophisticated lower classes it might be new--but would this interest them? I think not."

"Informative, easily understandable by average viewer, well coordinated and presented--those 30 minutes slipped out very quickly."

"Treatment of the subject was very thorough, detailed, and well planned."

"I asked my students to view the program and got favorable comments from those that viewed it."

Selected Comments -- "The Trembling Earth"

"Excellent--very appropriate to the times"

"The narration was dull, almost monotone, low key, and would not cause one to listen unless he already had strong interest in this subject."

"On the spot photography was terrific--especially the showing of the Alaskan earthquake."

"Excellent photography."

"As a teacher of earth science, I feel that the program was of great value to the student seeking knowledge in this field."

"Possibly tried to present too much information in the time allotted."

"I had the slight feeling that the technical jargon in "The Trembling Earth" might not be relevant to a layman in a 30-minute program."

"I felt the program was presented in a manner interesting to both a lay person and a scientist."

"As a prectising geophysicist, I felt there was too much use of technical jargon."

"It limited itself to specific area without too many scientific concepts presented."

"More animation and diagrams would help. Less emphasis on talk and personalities."

"It was an excellent program for earth and space science students because we discuss these waves as indicators of the earth's interior composition."

"My wife's interest was sustained, and she is not a scientist. I thought the program was quite well done."

"I teach 8th grade ESCP course and a film of this nature would be most valuable for classroom use, with little, if any, modification. In the words of another viewer, a lay person, 'This program is what makes TV worthwhile."

"I am a bit uncertain as to the extent the "great public" can absorb this kind of program, but I am, at the same time, convinced that this is the way to bring the public up to a higher level--not to pander to their ignorance, as is so often done."

"Work of seismologist presented well, without being too technical."

"It was unfortunate that it was not an hour long."

"The program lacked the attention-keeping devices."

"Enclosed are some of the comments made by my ninth-grade students:
'I thought last night's program was pretty good and I'll have to admit that I enjoyed it.'
'I thought it talked too much about the machines and not enough about earthquakes, what causes them, the effects of them.'
'It was interesting when they showed the evidence of faulting on the earth.'"

"My overall reaction, and that of the lay viewers with whom I have spoken about it, was very favorable indeed. Suggest you consider doing similar films of such newsworthy topics as continental drift and seafloor spreading, pollution, and natural resources."

"The absolute highlight was the magnetic tape replay of that first pulse of the recording pen (of that Good Friday, 1964)."

"The major weakness was the competition of the Carol Burnett Show on commercial TV."

"I considered this program so important that it was a homework assignment for all my classes."

"Core, mantle, and crust were mentioned; but no diagram presented illustrating these features and the passing of seismic waves through them."

Selected Comments -- "Stop or Go"

"The lay person may have been impressed by the complexity of the experiment but I doubt whether he will consider the result worth the effort."

"Excellent portrayal of methodology in experimentation."

"Tedium of research suitably brought out."

"The fundamental principles of the experiments were covered too rapidly."

"I personally feel that this type of programming should be one of the more dominating functions of TV."

"A well conceived and excellently presented program. I hope your efforts in this area can be continued."

"I hope this series is received with sufficient enthusiasm to encourage further endeavors by NET."

"Too many scientific terms were used without defining them."

"I have seen the astronomy film and the seismology film. It seems to me that this one is better in describing the breadth of background information and the actual "work" that goes into scientific investigation."

" I think very highly of your "Spectrum" programs and recommend them to my science students."

"Why use RNA when DNA is the major concept taught to youngsters. Why select such difficult and complex work, when there are much easier ones to demonstrate."

"Some of the scientists came through as rather overconfident and a bit snobbish and conceited, an impression that young students dislike."

"For my Advanced Placement Biology students, it was most valuable, in that it presented the techniques used in modern bacteriological genetics studies. It was a bit too technical for an audience with a limited or non-recent Biology background."

"This program was reviewed by my adult evening class near the end of their course in genetics. We thought that this was not a typical genetics experiment for two reasons. 1) The title should have been "An Experiment in Molecular Genetics". 2) The efforts and independence of individual scientists seemed distorted by a "big team" image led by a sort of "scientific dictator." On the other hand, the graphics were good."

"Marvelous blending of animation and live action."

"I assigned this as a task for my class in biology. They are 28 10th graders in an honors section in BSCS Green Version Biology. They are presently involved in the units on genetics, having studied cell chemistry and structures and the DNA model and theories. They were given no background on the show, except the time and title. I am enclosing their reactions. Not all of the group, turned in evaluations, but in today's discussion they supported the evaluations enclosed."

"Would have liked more animated diagrams."

"How can I help educational TV? It is good. It is worth my students' time. It is worth the public's time.

"The programs actually bored the non-scientific members of my family in contrast say to the programs on earthquakes and weather."

"Even as a geneticist and being familiar with the work of Dr. Zinder, I had difficulty following some of the steps in his experiment as depicted in the film."

"Language was too technical. Program might be described as showing the daily life of geneticists, but really didn't explain anything."

"Basic information was clearly explained in language easily understood by the average layman.

"I thought the program was not only badly directed but downright boring, and I doubt that I would have watched more than the first few minutes if Dr. Zinder were not a personal friend of mine."

Selected Comments -- "A Visit With Harold Urey"

"We think the broadcast should have started with a brief outline of Urey's many contributions to science--which would have given relevance to his comments on atomic bombs, space exploration, and the educational system."

"In some respects I think Urey could have been presented as a more dynamic person."

"The presentation would have been more interesting if it were more dramatic."

"The program was entirely too stilted and unappealing to an average high school student."

"A Visit With Harold Urey" sounded more like a political platform than anything else."

"I would have liked to hear much more about Urey's own past and about men with whom he has worked."

"This program did much to show the human side of science and to discredit the image of scientists as cold, calculating individuals."

"I believe this program would have been of limited value to the layman. A fairly sophisticated science background was needed to understand many of the items discussed."

"I think it is good for the lay public to see what scientists do and how they are doing it."

"Interview was excellent; the moderator was very well versed and skilled in his field."

"It was very interesting to me, but to most I think it was a bore. The interview might as well have been on radio. There was no attempts to use TV techniques."

Appendix D

Tables
(Seismology)

Adult Sample

TABLE I - MASTER TABULATION - Page 1

Group I - 15
II - 26
III - 15
IV - 20
V - 32

Score

Group Mean (Total) 4.16

THE TREMBLING EARTH

Please answer the following 19 questions in order. Do NOT change any of your answers and do NOT go back to any previously answered questions.

1. Would you have watched "The Trembling Earth" on TV at home, if you had known about such a broadcast? 20 yes 17 no

2. Do you feel that enough explanations of terms and processes were offered in the film? 78 yes 30 no

3. Did the film hold your interest? 99 yes 15 no
(see Table VII)
Please explain briefly why it did, or did not: (refer to TABLE VII)

4. In your opinion, which of the groups listed below would benefit most from seeing this film?

   a) Geologists 23
   b) Scientists other than geologists 26
   c) The general public 56
   d) Persons who might choose geology as a career 59
   e) People who live in an earthquake-prone area 54

5. Do you feel you gained some knowledge about:

   a) the behavior of the earth's crust 88 yes 20 no
   b) the interior of the earth 60 yes 46 no
   c) the way scientific information is gathered 93 yes 13 no
   d) the way it is evaluated 72 yes 34 no
   e) the nature of waves 55 yes 52 no

6. Did you know what a seismograph is before you saw this film? 74 yes 34 no

7. If you did not know, do you know now what it is? 20 yes 14 no

8. What actually does a seismograph record?
Seismic waves of earth's crust (bedrock)
Movement of earth's crust
Shock waves caused by shifts in earth

9. What is the basic design of a seismograph?
Inert pendulum recording earth's shock waves; pendulum in a magnetic field one part moves with earth while other does not due to inertia--such movement is electronically recorded after movement is translated into electrical impulse.

10. Why does the seismic station in the mine use several different kinds of seismographs?
Measures-records waves in different layers of earth
Measures crust movements in different directions
To record differnt frequencies of waves; record different kinds and sources of waves; on different instruments for unscrambling and interpretation.

THE TREMBLING EARTH

11. Why does each seismograph also record the exact time?
Interelate and locate shock
Help correlate data with other instruments
Location and duration of quake

12. What exactly is measured by the instrument shown which consists of a 200 ft. long quartz tube?
Difference in movement of two ends of tube; movement of bedrock
Stretching and compression of earth's crust; relative movement of the bedrock at the two ends of the tube.

13. What are the crust, mantle and core of the earth?
Different layers of the earth (1-2-3)

14. What causes an earthquake?
Rupture in the crust, pressure under surface; warping and rupture of earth due to geological forces. Internal pressure relieved through movement of earth's crust. Movement of the earth's crust; pressure along fault zone.

15. Why do waves generated by one earthquake shock arrive at great time intervals at the same seismic station?
Different waves move at different speeds in different layers of earth.
First waves in high frequency ranges

16. What is a fault?
Flaw in earth along which quake can occur
Break in earth's crust
Pre-existing zone of weakness

17. What knowledge, other than the fact that an earthquake has occurred, do seismologists gain?
Where it has occurred, duration and extent of quake and rupturing after-shock. When and approximately how often quakes may occur.

18. How do seismologists pinpoint the location of an earthquake from their records?
Intersection of time intervals of different waves compared to known values; comparing present data with past records; measure arrival times of first waves compared to known values--and analyzed data from three seismographs.

19. What exactly was meant by the term "noise" as used in the film?
Noise of civilization, non-quake noise.

TABLE II

Results of Group I (Fundamentals of Film Production, WSU, four credits, undergraduate course) (Credit Students)

15 people 10 April 1969 3 p.m.

THE TREMBLING EARTH

Mean score 7 1/3
Possible score 12.0

Please answer the following 19 questions in order. Do NOT change any of your answers and do NOT go back to any previously answered questions.

1. Would you have watched "The Trembling Earth" on TV at home, if you had known about such a broadcast? 9 yes 6 no

2. Do you feel that enough explanations of terms and processes were offered in the film? 12 yes 3 no

3. Did the film hold your interest. 12 yes 3 no

   Please explain briefly why it did, or did not:

4. In your opinion, which of the groups listed below would benefit most from seeing this film?

   Geologists 0
   Scientists other than geologists 2
   The general public 7
   Persons who might choose geology as a career 8
   People who live in an earthquake-prone area 5

5. Do you feel you gained some knowledge about:

   a) the behavior of the earth's crust 11 yes 4 no
   b) the interior of the earth 5 yes 10 no
   c) the way scientific information is gathered 13 yes 2 no
   d) the way it is evaluated 8 yes 7 no
   e) the nature of waves 6 yes 9 no

6. Did you know what a seismograph is before you saw this film? 14 yes 1 no

7. If you did not know, do you know now what it is? 1 yes 0 no

8. What actually does a seismograph record?
   1

9. What is the basic design of a seismograph?
   1

10. Why does the seismic station in the mine use several different kinds of seismographs?

TABLE III Results of Group II (Contemporary Thought and Writing) (Housewives)

26 people First film shown 15 April 1969 1 p.m.

THE TREMBLING EARTH

Mean score 3.5
Possible score 12.0

Please answer the following 19 questions in order. Do NOT change any of your answers and do NOT go back to any previously answered questions.

1. Would you have watched "The Trembling Earth" on TV at home, if you had known about such a broadcast? 23 yes 2 no

2. Do you feel that enough explanations of terms and processes were offered in the film? 20 yes 6 no

3. Did the film hold your interest? 26 yes __ no

Please explain briefly why it did, or did not:

4. In your opinion, which of the groups listed below would benefit most from seeing the film?

Geologists 4
Scientists other than geologists 6
The general public 18
Persons who might choose geology as a career 18
People who live in an earthquake-prone area 14

5. Do you feel you gained some knowledge about:

a) the behavior of the earth's crust 22 yes 2 no
b) the interior of the earth 20 yes 4 no
c) the way scientific information is gathered 24 yes 0 no
d) the way it is evaluated 18 yes 6 no
e) the nature of waves 16 yes 9 no

6. Did you know what a seismograph is before you saw this film? 21 yes 5 no

7. If you did not know, do you know now what it is? 3 yes 2 no

8. What actually does a seismograph record?

2.0

9. What is the basic design of a seismograph?

.0

10. Why does the seismic station in the mine use several different kinds of seismographs?

TABLE IV   Results of Group III (ATTAC - Basic Writing Class)   (Poverty Program)

15 people (14 negro female, 1 white male)   17 April 1969   10 a.m.

THE TREMBLING EARTH

Mean score 2.5
Possible score 12.0

Please answer the following 19 questions in order. Do NOT change any of your answers and do NOT go back to any previously answered questions.

1. Would you have watched "The Trembling Earth" on TV at home, if you had known about such a broadcast? 14 yes 1 no

2. Do you feel that enough explanations of terms and processes were offered in the film? 8 yes 6 no

3. Did the film hold your interest? 14 yes 1 no

Please explain briefly why it .did, or did not:

4. In your opinion, which of the groups listed below would benefit most from seeing the film?

Geologists 5
Scientists other then geologists 7
The general public 6
Persons who might choose geology as a career 5
People who live in an earthquake-prone area 10

5. Do you feel you gained some knowledge about:
a) the behavior of the earth's crust 12 yes 3 no
b) the interior of the earth 8 yes 7 no
c) the way scientific information is gathered 11 yes 4 no
d) the way it is evaluated 7 yes 8 no
e) the nature of wave 6 yes 9 no

6. Did you know what a seismograph is before you saw this film? 4 yes 11 no

7. If you did not know, do you know now what it is? 5 yes 6 no

8. What actually does a seismograph record?

4.5

9. What is the basic design of a seismograph?

.0

10. Why does the seismic station in the mine use several different kinds of seismographs?

TABLE V Results of Group IV (Beyond 60: Sounds of Silence) (Senior Citizens)

20 people 17 April 1969 1 p.m.

THE TREMBLING EARTH

Mean score 2.4
Possible score 12.0

Please answer the following 19 questions in order. Do NOT change any of your answers and do NOT go back to any previously answered questions.

1. Would you have watched "The Trembling Earth" on TV at home, if you had known about such a film? 18 yes 2 no

2. Do you feel that enough explanations of terms and processes were offered in the film? 14 yes 6 no

3. Did the film hold your interest? 20 yes ___ no

   Please explain briefly why it did, or did not:

4. In your opinion, which of the groups listed below would benefit most from seeing the film?

   Geologists 8
   Scientists other than geologists 8
   The general public 8
   Persons who might choose geology as a career 13
   People who live in an earthquake-prone area 14

5. Do you feel you gained some knowledge about:

   a) the behavior of the earth's crust 18 yes 2 no
   b) the interior of the earth 13 yes 7 no
   c) the way scientific information is gathered 17 yes 3 no
   d) the way it is evaluated 17 yes 3 no
   e) the nature of waves 13 yes 7 no

6. Did you know what a seismograph is before you saw this film? 14 yes 6 no

7. If you did not know, do you know now what it is? 4 yes 2 no

8. What actually does a seismograph record?

   1.5

9. What is the basic design of a seismograph?

   .5

10. Why does the seismic station in the mine use several different kinds of seismographs.

TABLE VI Results of Group V (Saturday classes: Writing and Languages) (Workshop and general)

32 people 19 April 1969 10 a.m.

THE TREMBLING EARTH

Mean score 5.1
Possible score 12.0

Please answer the following 19 questions in order. Do NOT change any of your answers and do NOT go back to any previously answered questions.

1. Would you have watched "The Trembling Earth" on TV at home, if you had known about such a broadcast? 26 yes 6 no

2. Do you feel that enough explanations of terms and processes were offered in the film? 24 yes 8 no

3. Did the film hold your interest? 27 yes 5 no

Please explain briefly why it did, or did not:

4. In your opinion, which of the groups listed below would benefit most from seeing this film?

Geologists 6
Scientists other than geologists 3
The general public 17
Persons who might choose geology as a career 15
People who live in an earthquake-prone area 11

5. Do you feel you gained some knowledge about:

a) the behavior of the earth's crust 25 yes 7 no
b) the interior of the earth 14 yes 18 no
c) the way scientific information is gathered 28 yes 4 no
d) the way it is evaluated 22 yes 10 no
e) the nature of waves 14 yes 18 no

6. Did you know what a seismograph is before you saw this film? 21 yes 11 no

7. If you did not know, do you know now what it is? 7 yes 4 no

8. What actually does a seismograph record?

1.5

9. What is the basic design of a seismograph?

2.0

10. Why does the seismic station in the mine use several different kinds of seismographs?

TABLE VII

THE TREMBLING EARTH

Question 3

Why (did) (did not) film hold your interest?

Did	Number of times cited	Did Not	Number of times cited
Vivid illustration (Actual film of quake)	17	Narrator's voice slow and lacked variety	6
Knowledgeable speaker	1	Some of the photography dull	2
Fascinating subject	12	Too much like a school lecture	1
Current event - covered in other media	13	Too hard to follow	1
Well organized	11	Some terms not explained (seismic)	2
Because I have been to Alaska	3		
Documentary interest	3		
I am interested in science	4		
Learn something new	4		

Appendix F

Genetics Reaction Form

STOP OR GO - AN EXPERIMENT IN GENETICS

Questions for Audiences

Please answer the following 14 questions in order. Do NOT change any of your answers and do NOT go back to any previously answered questions.

1. Would you have watched "Stop or Go - An Experiment in Genetics" on TV at home, if you had known about such a broadcast? ___yes ___no

2. Do you feel that enough explanations of terms and processes were offered in the film? ___yes ___no

3. Did the film hold your interest? ___yes ___no

   Please explain briefly why it did, or did not:

4. What is the genetic code?

5. What does a geneticist do and why?

6, Why is an organism like a virus used in genetic research?

7. What is the relationship between the genes of all living creatures?

STOP OR GO - AN EXPERIMENT IN GENETICS

8. What is DNA?

9. Aside from the material benefits of scientific research what else does science offer society by way of example?

10. How are scientists like or dislike the rest of society?

11. Give the conditions necessary for performing an experiment?

12. Do scientists always know the results of their experiments before they perform them?

13. What is the role of the individual scientist in relationship to the community of scientists?

14. Should the work of scientists always be directly related to human benefit?

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